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# Michael Faraday


BY W. F. G. SWANN

*Director, Bartol Research Foundation of the Franklin Institute*


IT IS a matter of common occurrence to find a man without formal training in scientific matters fired with an enthusiasm for investigations to an extent which causes him to devote his life in an endeavor to extend the boundaries of knowledge. Sometimes such a man develops into a successful inventor, who, without having necessarily very much appreciation of the formal structure and relationship of the different portions of science, nevertheless, with ingenuity, perseverance, and intelligence, proceeds to perfect appliances which become of outstanding benefit to the world.

When the untrained amateur turns his attention to the fundamental principles of science, however, he too often becomes absorbed in vain speculations as to the ways of the universe, speculations which grow in his mind to the status of dogmas, and ultimately land him in the realm of that large group of his fellows so much of whose time is spent in seeking recognition and pestering men of science with their pet theories. They claim that their way of thinking is not that of other men, and usually are saturated with a peculiar kind of arrogance which persuades them to the belief that everyone who fails to accept their views is bound in cast iron bonds of conventionalism and bent upon persecuting them as the various other martyrs of science whom they cite were persecuted in the past. When one realizes the hopelessness of trying to represent to such individuals the errors of their ways, or at best the futility of their ideas, one is at times apt to feel that organized training in science is necessary if the mind is to avoid the various pitfalls and barren wastes so plentiful in unorganized thought.

It is, therefore, a peculiar comfort to those who may fear the sterilizing effect of conventional training to see in Michael Faraday an example of a man without any of the advantages of a scholastic career, who, animated by an enthusiasm for science but forced through lack of training in the customary modes of scientific thinking to adopt his own methods of approach, was yet successful in creating a systematic organized scheme of thinking peculiar to his own powers, and such as to result in the discovery of the fundamental principles and ideas involved in a realm of science, which of all realms might be regarded as that least adapted to discovery by the untrained investigator.

## Started as Newspaper Boy

Inheriting no advantages in the shape of a share in this world's goods, and with no influence behind him beyond that necessary to secure a position as a newspaper boy, and subsequently one as an apprentice to a bookbinder, Michael Faraday started his career. The bookbinding business at least provided him with the opportunity of coming into contact with literature and with scientific writings in particular; and, such meager fragments as he was able to gather in this way served to fire that spark of enthusiasm for science which caused him to forsake the trade which he had spent so much time in learning and which at least provided him with safe livelihood, for the very precarious existence of a philosopher, and to seek entrance into the realm of science by accepting a very humble position as assistant at the Royal Institution of London. He was appointed at the age of 22, and his duties seemed to have covered every field from acting as personal valet to Sir Humphrey Davy during his European trip, to scientific investigator.

The luxury of elaborate machine shops and many research assistants was not known in the day of Faraday, and most of the practical burden of the experimental work, and of the preparation of the lecture experiments for the Institution must have fallen upon him in the earlier years of his activities. Even in this humble capacity, however, we find his mind playing upon all fields. The account of his trip abroad with Sir Humphrey Davy is rich with reminiscences and meditation upon all manner of subjects—upon art, upon religion, upon the ways and customs of the different people he encountered, upon the philosophy of life and a hundred other things. He heard many lectures at the Royal Institution, and formed his own opinion upon the lecturers and upon how a lecture should be conducted; and, he writes an account of this matter in a letter to his friend Abbot, an account which might very well serve as good instruction to many lecturers today.

Faraday's earlier investigational work which was the outcome of the researches of Sir Humphrey Davy, embraced chemical subjects, and in particular the liquefaction of gases. This work was of sufficient merit to result in his election to the directorship of

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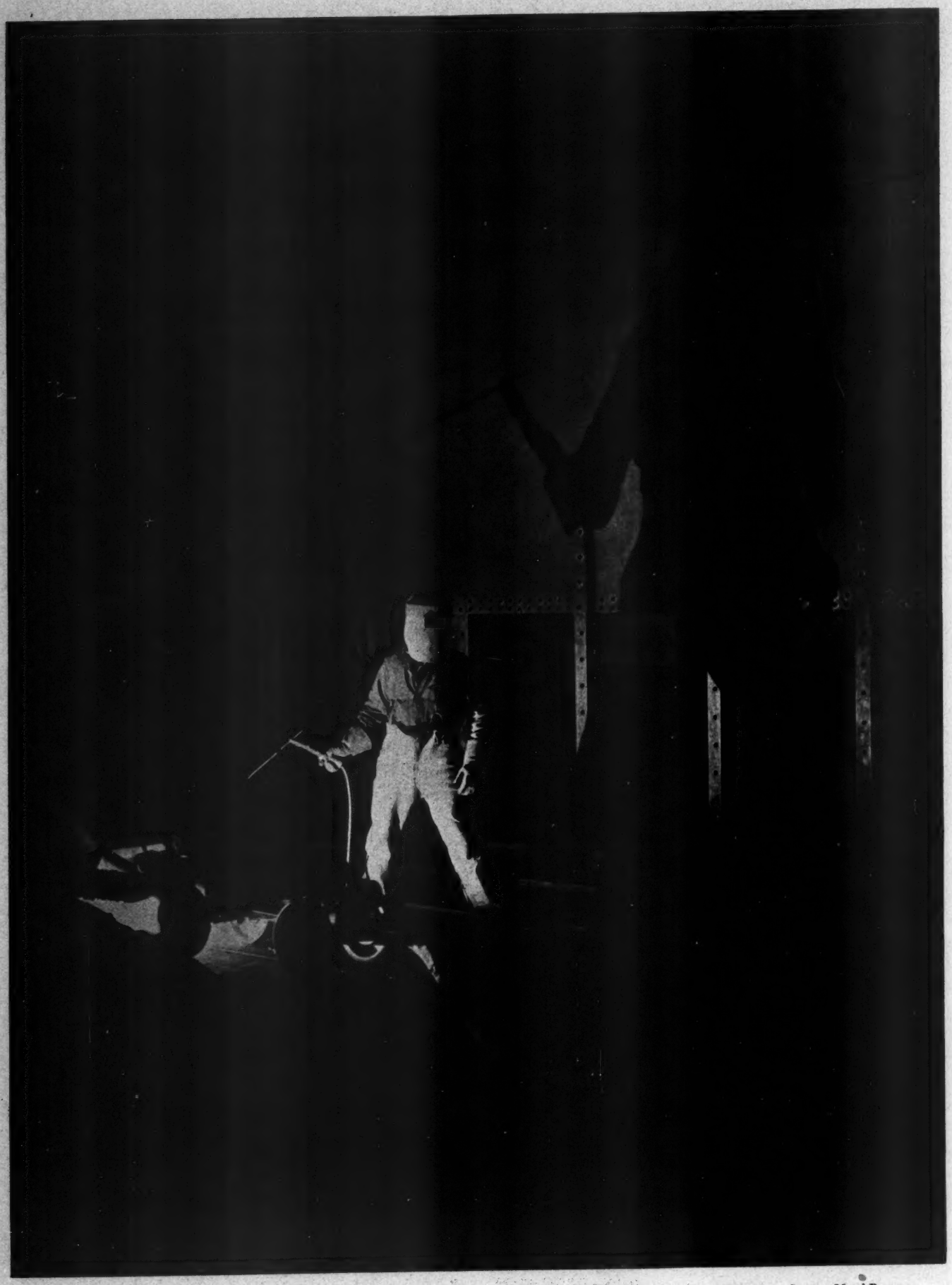

*Illustrations Courtesy* Metal Progress.

**The Arc Welder**

# Arc Welding in Machinery Manufacture

BY A. F. DAVIS

*Vice-President, Lincoln Electric Company, Cleveland*

FOR many years casting and riveting have been regarded as the basic methods of fabricating all types of mechanical and structural designs, but today arc welding, a comparatively new fundamental manufacturing process, has become recognized as one of the important manufacturing processes in fabrication. The electric arc fuses the metals of a product together at the joints making the entire design one integral unit of steel.

A few applications will illustrate how this is done. A large 1000 ton press, the frame of which is fabricated completely by the arc welding process, has as an interesting feature the method of building up the double C frames. Eight half inch plates, 14 feet high and 7 feet 6 inches wide, were cut to shape and the edges beveled. Studs seven-eighths inch in diameter were placed with hexagonal nuts so located as to space the inside plate faces four inches apart. The holes in the plates were countersunk and the plates were drawn together by temporary hexagonal nuts on the ends of the studs. While bolted together in this manner, each side plate was arc welded to a base plate two inches thick. As each plate was arc welded to the base, the nuts on the studs were removed and the plates were arc welded to the studs through the countersunk holes. The weld was chipped flush with the surface of each plate before the next plate was put in place.

Use on this press of these lighter plates, instead of the heavier two inch plates, was due, among other reasons, to the fact that the thinner plates were easier to handle, and the manufacturer was better equipped to cut them to shape. However, by arc welding these plates into place the same strength and rigidity as might have been had by using a two inch plate was given to the frame of this large press.

A recently built feed mill is an example of the improved appearance of a machine redesigned for arc welded construction. The moving parts are completely enclosed and the machine is stronger and more rigid. The new machine is so designed that it can be assembled or disassembled quickly, and all parts are readily accessible for cleaning. It was also necessary to keep the cost of this new machine equal to or less than its prototype; all these requirements are met by the rolled steel, arc welded construction. Another point that is well illustrated in this feed mill is that careful planning and designing makes it possible to conceal all welds. Many designers criticize arc welded construction on the ground that the exposed welds are unsightly. This machine has no welds exposed, and its smooth surfaces, which are easily painted and cleaned, give it a most pleasing appearance.

## Shielded Arc

A late development in arc welding has been the introduction of the shielded arc. This new process produces welds on mild rolled steel with a tensile strength of sixty to seventy-five thousand pounds per square inch that are extremely ductile and highly resistant to corrosion.

The principle of the shielded arc consists of preventing the oxygen and nitrogen in the ambient atmosphere from combining with the weld metal while in the molten state. It is common knowledge among those familiar with arc welding that the molten weld metal as it is being deposited has an affinity for oxygen and nitrogen. Since the arc stream is maintained in an atmosphere composed chiefly of these elements, oxidation proceeds at a high rate during the passage of the weld metal from electrode to work. In this way oxides and nitrides are formed in the weld metal. It is the presence of the oxides and nitrides in the weld metal which impairs its strength, ductility and resistance to corrosion. If the molten weld metal is protected from contact with atmospheric oxygen and nitrogen during the process of deposition, the weld so produced will be free of oxides and nitrides.

In one process of manual welding, a completely shielded arc is obtained through the use of an extruded type of heavily coated electrode. The metal core of this electrode melts faster in the arc than the coating burns. Thus, the projected coating forms in effect a crucible in which the electrode metal is melted. This crucible or projected coating shields the arc stream from the surrounding atmosphere for almost its entire length. However, as the edge of the projected coating burns in the arc, quantities of carbon monoxide are

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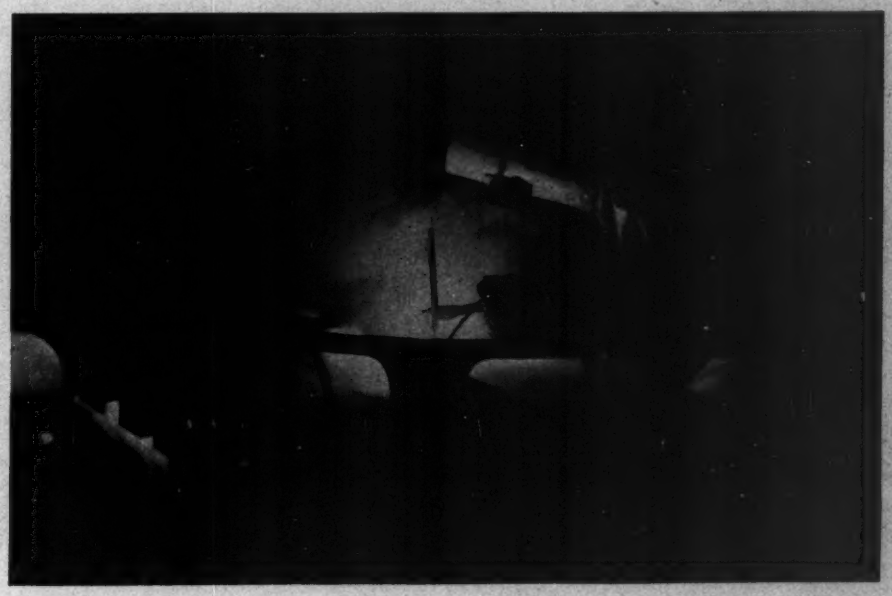


*Arc welding a joint. The worker must wear a mask with a window of colored glass to protect him from the heat and intense glare.*

# The History of Electrical Engineering

BY W. H. TIMBIE

*Professor of Electrical Engineering and Industrial Practice, M. I. T.*

THE history of electrical engineering is the story of the discovery and investigation of the nature of magnetism and electricity and of their applications to the service of mankind. It is a history not only of discovery and invention but also of the development of great business enterprises to the end that these discoveries and inventions shall add to the convenience and comfort of this old world of ours. The story is that of three periods of history.

The first is a period of approximately two hundred years, beginning with the discovery of magnetism and static electricity. During all this time the nature of the phenomena discovered was a complete mystery. The lodestone, the rubbed catskin and the pieces of amber were objects of curiosity for the intellectual and the curious but of no practical application to the arts.

The most important discoveries during the long first period of two hundred years may be summed up as follows:

In 1600 William Gilbert, court physician to Queen Elizabeth, published his "De Magnete" ("On the Magnet") which contained the result of his researches on the lodestone. This is a really remarkable book and represents all that was then known about magnetism. The Vail Library contains a very valuable copy of the first edition of this work. Gilbert was the first to introduce the word "Electricity."

In 1752 Benjamin Franklin proved that lightning and static electricity were identical, and in 1791 Luigi Galvani, an Italian physician, published the result of his long years of painstaking research on animal electricity.

Slight progress for two hundred years, but tremendous when compared with the progress made in all the thousands of years which had gone before.

*EDITOR, teacher, and author, Professor W. H. Timbie is well qualified to write about the "History of Electrical Engineering." After graduating from Williams College he became an instructor at the Pratt Institute, and later, head of Applied Science at the Wentworth Institute. He was Editor-in-Chief of the War Department Committee on Education and Special Training for a year, then came to the Institute in 1919 as Professor of Electrical Engineering and Industrial Practice. He is now in charge of the cooperative courses in the Department of Electrical Engineering.*

## Volta's Pile Starts Second Era

The second era is a period of a little over fifty years extending from the beginning of the nineteenth century up to the time of the Civil War. It really started with the invention of Volta's pile in 1799, which for the first time gave the experimenters a source of electric energy. The impetus thus given rapidly led to complete experimental investigations of the physical nature of electricity by Faraday, Ohm and Oersted and then to the formulation of mathematical laws for the fundamental concepts by Ampere and Gauss. This period is unparalleled in history for the amount of scientific knowledge discovered by pure scientists and experimentalists. At the same time it marked the beginning of the industrial era when railroads, steamships, the iron industry and many other activities made marked progress toward the development of our present civilization. Yet this period produced a minimum of commercial exploitation.

Throughout the first twenty years of this era after Volta's invention the electric current thus generated was used almost solely to separate chemical compounds into their component parts, although Sir Humphrey Davy in 1808 had used it to produce an electric arc light between two carbon rods. Then in 1820 H. C. Oersted of Copenhagen, discovered that an electric current produced a magnetic force, and five years later William Sturgeon, an English soldier, made the first electro-magnet. This furnished the fundamentals of the apparatus with which Michael Faraday made his famous discovery in 1831, of electro-magnetic induction, and his equally famous invention of the disk electric generator. Within a year the disk had been replaced with a wound armature, and a commutator added, but it was nearly thirty years before anyone thought of replacing the permanent magnet with an electro-magnet excited by a current from the armature.

In America, Joseph Henry, a professor of natural philosophy at Princeton, had discovered the principle of self induction in 1832, and laid the foundation for the inventions in 1837 of the electric telegraph by Morse, and the electric motor by Thomas Davenport, a Vermont blacksmith.

The third period extends from the end of the Civil War up to the present time and is the era in which electrical engineering came into existence as the art of applying the known science of electricity to the use and convenience of man. In the ten-year period immediately following the Civil War are recorded not only the results of inventive genius, but also the founding of entirely new industries destined in ways totally unexpected to change human relations, our system of education, and in fact our whole character of living. It is in this period that we find the beginning of the electric light industry, the light and power industry, the telephone industry, electric street railways and the development of the steam turbine. At the same time, in the United States, leaders, political and otherwise, recognized the necessity of establishing schools of a different type, called for the most part Schools of Mechanic Arts. It was at this time also that the Naval Academy and private schools of technology came into being. With them came a professional engineering consciousness resulting in the establishment fifty years ago of such societies as the American Institute of Electrical Engineers, American Society of Mechanical Engineers, and the Society for the Promotion of Engineering Education.

The establishment and successful guiding of great industrial organizations in this era are linked with such names as Charles A. Coffin, George Westinghouse, Theodore N. Vail, Thomas A. Edison and Elihu Thomson. It is largely due to the organizing genius

(*Continued on page 143*)

# A Million Volt Air Condenser

BY A. P. M. FLEMING

*Director-Manager, Research and Education Departments, Metropolitan-Vickers Company, Manchester, England*

WITH the rapid growth of high-voltage engineering in the last decade it has become of ever-increasing importance to advance our knowledge of the performance of insulation materials and dielectrics in general when operating under high voltages. We have seen on the one hand the growth of high voltage laboratories for the routine testing of insulation materials used in transmission-line engineering, such as porcelain insulators, condenser and oil-filled bushings and cables, and on the other hand there have been a number of laboratories constructed and equipped expressly for the purpose of pursuing fundamental research into the nature of dielectrics and investigating on an extensive scale the modifications and improvements in the construction of high-voltage apparatus.

Routine testing of course does not often extend into the region of voltages very high as judged on present day standards; for example, the maximum voltage we apply to the 132 kv. bushings used on the British Grid transmission system is only of the order of 400 kv; but in laboratories engaged upon pioneer work, pressures up to one million volts are very frequent. Here it is necessary to extend the bounds of our knowledge of insulation far beyond the immediate requirements of the industry, to explore new materials and to devise tests which shall imitate as far as possible the various phenomena to which insulation is subjected in service. In this region of very high voltages the problem of the accurate measurement of voltage becomes more difficult than at lower voltages; thus potentiometers whether for power frequencies or for impulsive discharges are more complicated owing to the disturbing influences of stray brush discharges and neighboring objects whether at earth or high potential. Nevertheless, despite the increased difficulties, the importance of an accurate measurement of voltage at power frequencies is such as to demand the most careful consideration.

It will be realized upon a little reflection that the use of the sphere gap as an ultimate standard of reference for voltage measurement is merely begging the question, since a sphere gap is only a secondary standard itself requiring calibration. Its calibration depends on a knowledge of the break-down value of air under uniform electric stress, which figure has had to be determined experimentally. Any external object which can exert an influence on the shape of the field between the spheres therefore upsets the calculated breakdown value for the gap, the extent of the error easily amounting to 5 per cent. Calibration curves of sphere-gaps in different laboratories in the world have brought out this dangerous uncertainty of voltage measurement to a marked degree and for this reason it is better to rely on more fundamental methods of measurement.

An obvious method of measurement is to determine the charging current of a condenser stressed to the voltage it is required to measure. Given the charging current, the capacity of the condenser and the frequency with which it is charged, the voltage to which it is charged is immediately deduced, and it can be shown that the value obtained is independent of small oscillations or irregularities which may be present on the alternating voltage wave. Provided that the capacity of the condenser is not affected by movable objects in the neighborhood of the condenser, the method will remain independent of the disturbing factors in sphere-gap measurements. To a first approximation also the method is independent of pressure, temperature and humidity.

## Construction of Condenser

In some laboratories in which this method has been employed, the condenser has taken the form of a sphere gap of special construction, the earthed sphere being cut to form a guard ring about one small segment of the sphere opposite the high-voltage sphere. This, however, still suffers from the above mentioned disadvantage, interference from surrounding movable objects, and the method adopted has aimed at the complete elimination of interference by placing the condenser above the high voltage transformer, one plate actually resting on the transformer bushing and the other suspended from the roof of the laboratory. (See illustration.) This arrangement has a further important advantage, namely, that the apparatus for measurement of voltage requires no floor space to house it. One difficult problem in a high-voltage laboratory is to maintain adequate floor space for testing purposes whilst there is always a huge space never utilized in the higher reaches of the laboratory. The use of a sphere gap at ground level considerably reduces the available space; with the condenser placed as illustrated here this

(*Continued on page 140*)

*The million volt air condenser. One plate rests directly on the transformer bushing and the other is suspended from the roof. The distance between can be varied from six to twelve feet.*

# Application of Electricity to Chemistry

BY M. deKAY THOMPSON

*Professor of Electrochemistry, M. I. T.*

FARADAY'S great contribution to the knowledge of electro-chemistry is his law of electrolysis, discovered 99 years ago. According to this law the chemical change (expressed in equivalents) which takes place at the boundary between a metallic and an electrolytic conductor is proportional to the quantity of electricity that has passed this boundary and is independent of everything else. This law makes possible the calculation of the maximum amount of change that can be expected in any electrolysis and the per cent to which this expectation is fulfilled is called the current efficiency. This law is the most fundamental law in electro-chemistry, and is evidently of great practical importance. The chemical equivalent of electricity is called a faraday and equals 96,500 coulombs.

While Faraday's contribution to electro-chemistry was not a necessary forerunner of the applications of electricity to chemistry, nevertheless it is of the greatest importance as a guide in most of these applications, and it is therefore appropriate to consider him an important contributor to these developments.

The practical applications of the interaction of electricity and chemistry include electroplating and electroforming, the extracting and refining of metals in aqueous solutions and in fused salts, the production of chemicals in aqueous solution by electrolysis, and in electric furnaces both by electrolysis and by electric heat; the production of electrical energy from chemical reactions in primary cells and the storage of energy in storage cells, and some reactions in gases, as the oxidation of nitrogen and the formation of ozone.

The oldest of these industries are electroplating and electroforming, the results of the accidental discovery by Professors Wagner and Jacobi in 1830, that electrodeposits might be used for plating and copying. These industries were limited in scope as long as primary batteries were the only source of electricity, and were used mostly for gold and silver for jewelry and tableware. Now, however, many metals are used for electroplating besides silver and gold, such as nickel, zinc, tin, copper, brass, cadmium and cadmium-zinc alloy, lead, iron, and the last to be used and most difficult of all to plate is chromium. The current density required for chromium is from 100 to 300 amperes per square foot (10.8 to 35 amperes per square decimeter), at from six to twelve volts for a tank. It takes about fifteen times as much energy as an equivalent amount of nickel, but the thickness required is very much less than for nickel. While nickel is usually plated to a thickness of 0.0002 inch (0.0005 cm.) chromium is frequently only 0.00002 to 0.00004 inch thick (0.00005 to 0.00010 cm.). It is usually plated over nickel or copper. The solution used is chromic acid containing some sulfate.[1]

Most books are now printed from type made by depositing copper or nickel on wax negatives made conducting by graphite powder, and this same principle is used for many other purposes, such as making seamless tubes and decorating glass and china.

## Electrolytic Metal Extraction

The electrolytic extraction of metals was not successful at first because the methods tried were wrong in principle. For example, in attempting to extract copper, a copper matte was electrolyzed in a copper sulfate solution. Iron dissolved with the copper, and soon became so concentrated that it deposited with it. The extraction of copper and of zinc is carried out on a very large scale now, by leaching the ore in sulfuric acid, removing the impurities, and depositing the metal by the use of unattackable anodes. There is a large plant for copper at Chuquicamata, Chili, and for zinc at Great Falls. Recently a plant has been installed in Idaho for the electrolytic production of zinc, with a capacity of 50 tons a day, with provision for trebling the output. A current of 16,000 amperes at 500 volts is used. Zinc is deposited on aluminum cathodes and stripped off when about one eighth of an inch thick; the anodes are lead alloy. The current efficiency is about 85 per cent.

Electrolytic nickel averages 99.9 per cent in purity, and is the highest grade pro-

*Arc type electrolytic furnaces in which Aluminum Oxide is made.*

1Annual Rep. of Committee in Electrochem. and Electrometallurgy. J. Am. Inst. of E. E. 48, 878 (1929). The statistics in this article are from this report, and "The Mineral Industry" for 1929.

duced on a commercial scale. Cobalt cannot be removed from nickel in electrolysis.

In electrolytic refining of metals, the impure metal usually contains only one or two per cent of impurities. This metal is cast into anodes and is electrolyzed in a solution containing one of its salts, some acid, and a certain limited amount of impurities, as well as other substances in small amounts put into the solution to improve the form of the deposit. Some of the anode impurities do not dissolve, but go into the anode mud; the rest dissolve with the metal which is being refined, but only about one or two per cent of the amounts in the anode are deposited with the purified metal at the cathode, if their concentration is kept below the critical value by constantly purifying the solution.

In refining copper the cathodes consist of thin sheets of electrolytic copper, called starting sheets. Copper is deposited on both sides until the surface becomes so rough that they have to be replaced by new sheets.

Two of the most important products of electrolysis of aqueous solutions are chlorine and sodium hydrate, from sodium chloride. So many different cells have been devised for this purpose that it would take a volume to describe them. The difficulty is to keep the products separate after producing them. Other important compounds result if the products of this electrolysis are allowed to mix; these are hypochlorite, chlorate, and perchlorate. The last two are used in explosives, matches, and fireworks.

Water is electrolyzed on a large scale for the production of pure hydrogen and oxygen. A large number of cells have been devised for this process also, as this is another case where the products must be kept separate.

Hydrogen is used in the hydrogenation of oils, a process by which, in the presence of finely divided nickel, oils absorb hydrogen and are converted into fats. Pure hydrogen is also used in the synthesis of ammonia, the least expensive of all methods of fixing atmospheric nitrogen.

There are so many cases where electricity is needed at places where connection cannot be made to the mains of a power plant, that primary cells are of considerable importance. The most important of these are the Lalande type, consisting of copper oxide, sodium hydrate, and zinc, and the Leclanché dry cell, consisting of carbon, manganese dioxide, ammonium chloride, and zinc. Many millions of dry cells are used each year in this country alone.

The hope of finding a cell in which carbon and oxygen would unite through an electrolyte so as to produce electricity directly, thus furnishing a maximum of about 90 per cent of the total energy of this reaction directly as electricity in place of about 20 per cent by means of steam engines, is still the cause of an occasional piece of research, though the hope of success is more quiescent than it was once.

Storage batteries are used for traction, for starting automobiles, running submarines under water, regulating variable loads, and for insuring continuous service in electric supply systems.

## High Temperature Electric Furnaces

A very interesting and important branch of electrochemistry is that involving high temperatures in electric furnaces. Some of the products are made by the electrolysis of fused salts, as aluminum, sodium, potassium, cerium, (an iron alloy of which is used in gas lighters), magnesium and calcium. None of these metals can be produced in the presence of water. Sir Humphrey Davy in 1808 was the pioneer in this work.

Of all of these metals, aluminum is the most important; in 1929 the production in this country amounted to 225 million pounds. Aluminum is made by electrolyzing fused cryolite containing fifteen to twenty per cent of aluminum oxide. No doubt some other salt is added to lower the melting point,

*Illustrations Courtesy* Carborundum Co.

*Electric furnace used in large scale manufacture of silicon carbide. A resistance train is built up between the poles and coke, sawdust, salt, and sand packed around. The high heat fuses the whole mass into silicon carbide.*

for the cells are run at a temperature considerably below the melting point of the cryolite-aluminum oxide mixture. The required temperature is maintained by the electric energy supplied to the cells. The anodes are graphite or carbon, and are burnt by the oxygen liberated on their surface, so that the weight of anodes consumed is about ninety per cent of the aluminum produced. The cells in which the fused cryolite-aluminum is contained are iron casings, with flanges to assist radiation, lined with carbon. Aluminum is deposited in the bottom of the cell, and remains there until tapped.

Aluminum is used for aluminum paint, in the thermit process, and in many alloys in airplanes and automobiles, and for innumerable other purposes.

Magnesium is made by electrolyzing fused magnesium chloride with carbon anodes. This metal is lighter than the fused chloride, and floats on the surface, from which it is ladled without much loss. Castings for airplane engines are made from alloys consisting principally of magnesium, with 7 per cent of aluminum and 0.4 per cent of manganese.

Calcium is easily made by electrolyzing the fused chloride, but there is very little use for the pure metal. As it floats on the fused chloride and burns up rapidly at this temperature, the cathode is a cooled iron pipe to which the calcium freezes and is gradually drawn out of the bath. A calcium lead alloy, made by electrolyzing calcium chloride on a melted lead cathode, is used as a bearing metal.

It is a curious fact that pure barium has never been produced by electrolyzing any of its fused salts. Fused barium chloride will conduct, but at the

(*Continued on page 142*)

# Floodlighting

BY J. A. SUMMERS

*Director, Department of Floodlighting, General Electric Company, Nela Park, Cleveland*

*Cleveland Union Terminal.*

THE lighting of the Panama Pacific Exposition at San Francisco in 1915 was the first large scale lighting from concealed light sources; such lighting is essentially the principle of present-day practice. It is true that there were isolated cases of floodlighting previous to this time, but they were mostly of a temporary nature and accomplished by large arc searchlights. The Singer tower in New York was permanently floodlighted by this means about 1907. The Statue of Liberty and Washington Monument had also been lighted for special occasions by means of searchlights on battleships. But it was not until the development of the high wattage concentrated filament floodlighting lamps that commercial floodlighting came into its own as a potent advertising medium. Being virtually a new art, there was practically no information on the technique of handling the calculations and methods of design. Consequently, it was necessary to develop projectors, learn how to test them accurately and discover the best procedure for applying the data which was secured. Many experiments and trial installations were made before we were in a position to predetermine the results that would be secured.

The beautifying characteristic that floodlighting possesses was largely instrumental in its being enthusiastically welcomed from the start. It was early recognized that a tremendous amount of capital was tied up in purely aesthetic architecture. The very plainest of buildings would suffice for utility, but in order to make the buildings attractive it was necessary to spend considerable money in beautifying them. This is true not only of public but of commercial buildings as well. When night fell the daytime beauty of the building was lost, and therefore, in order that the capital invested in beautifying these structures might not be wasted, it was necessary that the building be lighted; thus revealing the beauties that would otherwise be unseen, and at a time when our public is most receptive.

## Lighting Promotes Interest

The lighting of public buildings promotes civic pride and tends to increase interest in government. On both large and small commercial buildings, it serves as an advertisement and usually produces definite revenue. Banks, as a general rule, are floodlighted; there is one drawback, however, which has prevented a much larger number from being lighted, and this can be attributed to the inability to finding a location for the projectors. The most common method of lighting these buildings is by means of a combination of ornamental street lighting units and floodlighting units, but where the building is of great size too many poles are required to hold a sufficient number of units. This not only detracts from the appearance of the bank, but quite frequently conflicts with local ordinances. In many cases these ordinances prohibit the erection of any type of poles in the down-town business district, and while these restrictions are reasonable, they are nevertheless responsible for the failure in lighting many of our beautiful buildings.

There are a great many considerations that must be given consideration in floodlighting buildings, such as the character and location of the building, its color, the foreground and background surroundings, and the local standards of lighting. These factors not only determine the intensity that is required to accomplish the desired results, but also determine to a large extent the character of the lighting. In a resort town where there are innumerable parks and amusements, a much more bizarre form of lighting is permissible, possibly even desirable, than in the staid dignified suburb of a purely residential character; here a dignified form of lighting is necessary. The architecture of the building

(*Continued on page 141*)

*The Chicago Merchandise Mart is a good example of industrial building floodlighting, utilizing the Chicago River as a mirror. 607 500 watt projectors are used.*

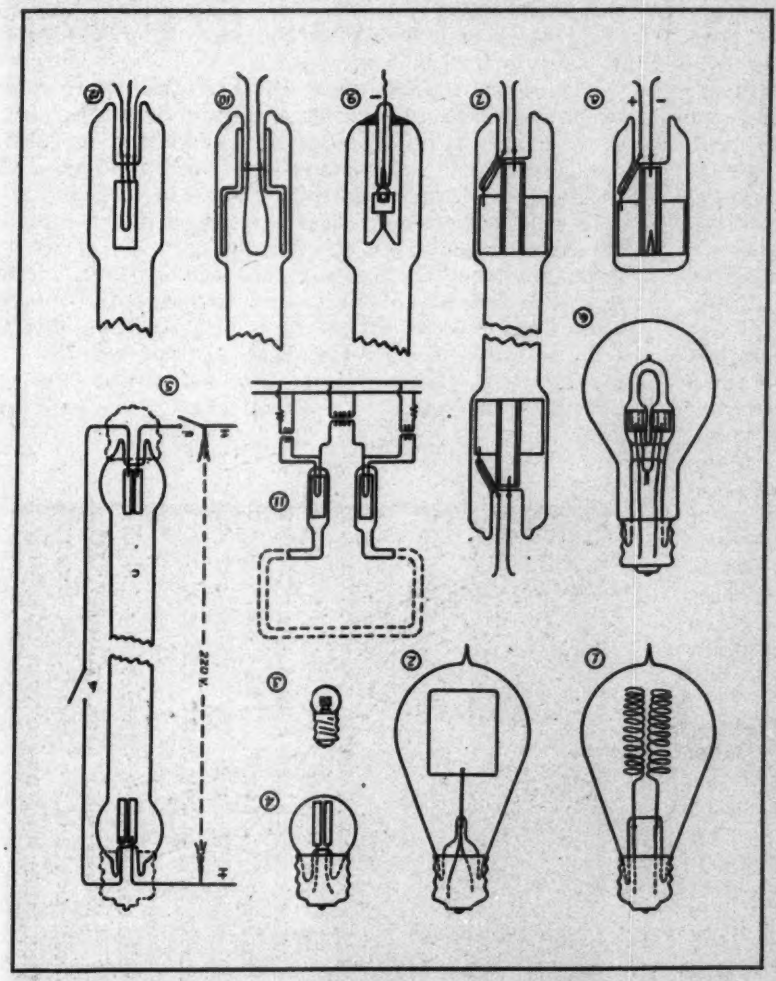
# Luminous Tubes

BY D. McFARLAN MOORE

*Manager, Moore Light Department, General Electric Company*

A COMPARATIVELY new commercial phase of artificial lighting has been exemplified by an innovation that has thrust itself not only upon the retinas of the millions of the inhabitants of the United States, but has also, in the form of luminous script signs, given a reddish hue at night to the main streets of most of the cities and towns the world over. Electricity passing through neon gas confined in glass tubes produces a luminosity so unusual due to its color and continuity, that it has compelled the attention of both the scientific and commercial fields of the earth.

The title, luminous tubes, can apply only to a single division of the very large present-day scientific infant known as gaseous conduction, the devices of which can be divided into the non-luminous which includes X-ray tubes, radiotrons, thyratrons, photo cells, etc., and the luminous, which is to be the general subject of this paper. It is helpful to also discuss the many different kinds of lamps under two general headings; namely, those having cold electrodes and requiring high voltage, such as the above referred to luminous signs, and those of more recent origin which will operate on low voltage, that is, less than 300 volts. Of the following 16 classes of gaseous conductor lamps, about one-half need only low voltage and of these the luminosity of one-half, in turn, is due to the scientific phenomenon known as the negative-glow, and the other half to its companion phenomenon, namely the positive column.



Positive column lamps would include, 1. script signs; 2. insitu tubes; 3. combined transformer and tube; 4. bulb with gas filament; 5. tubes using resonance. Low voltage positive column lamps would include, 6. hot cathode tubes; 7. electron gap tubes; 8. electron gas bulbs; 9. mercury vapor tubes; 10. oxide crater tubes. High voltage negative glow lamps would include, 11. tubes with large electrodes; and 12. bulbs with large electrodes. Low voltage negative glow lamps would include, 13. tubes having electrodes with special provision for electron emission; 14. the neon lamp in bulbs; 15. end-on bulbs; 16. intense corona in bulbs. Individual papers have been written on each of these sixteen classes.

## High Voltage

Not only was lightning the first gaseous conduction light but, of course, was produced by high potential, and high potential persisted with all artificial demonstrations of this kind of luminosity down through the Middle Ages and until only a very few years ago. Many felt that the elimination of high potential would be of great advantage or conversely, that if a tube or a gaseous conductor lamp could be made to successfully operate on the ordinarily distributed low voltage circuits of today, that not only would its field of usefulness be very greatly enlarged, but its efficiency would also very probably be greatly improved due to less cathodic voltage drop. Today the public considers all forms of gas lamps as new, because of the recent increase in their commercial introduction. Their basic and controlling technical principles were demonstrated some time ago. Nevertheless, detailed changes in the accuracy of design and selection of materials, due to the advances in the art of electronics, are proving of vital importance to commercial introduction.

All known gases were unsuccessfully tried about 1894 on 220 volts. Incandescent lamp bulbs were used but without heated filaments. The prediction was then made, that progress could only result by the discovery of some of the gases indicated by the table of the periodic law of the elements, and Ramsey and other great physicists were importuned. Before the beginning of the twentieth century the five monatomic elements had been announced, namely: argon, helium, neon, xenon and krypton. The experimental bulb lamps made in 1894, which required high voltage because they were filled with either $CO_2$ or nitrogen, were recharged in 1913 with neon, which only then became available, and the first low voltage gaseous conductor lamp was born. It needed no auxiliary apparatus

(*Continued on page 136*)

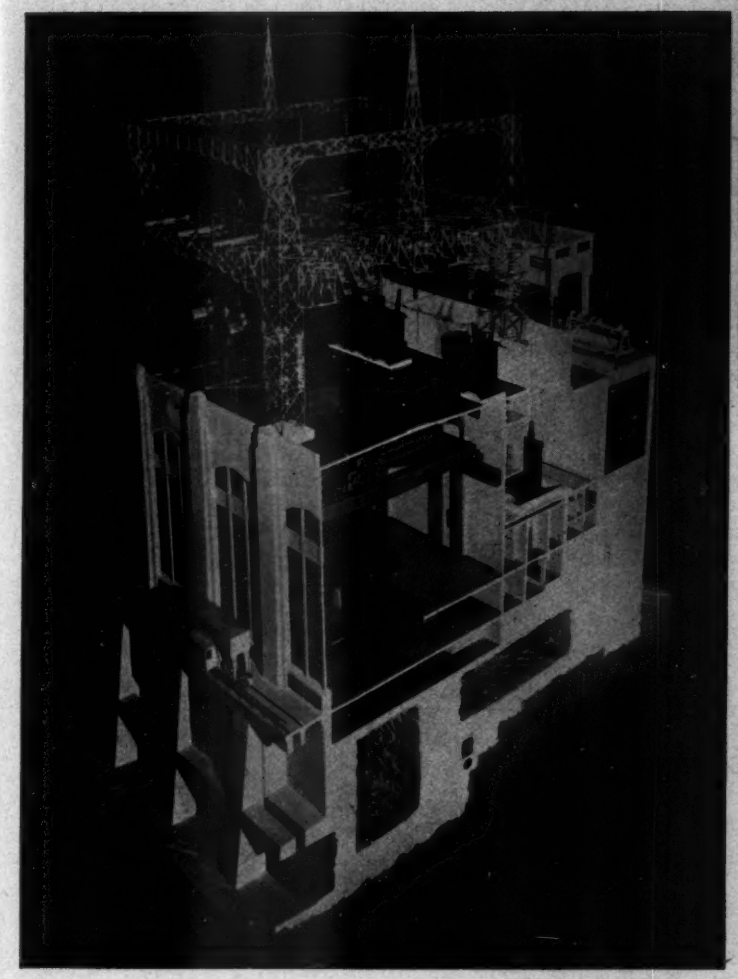
Courtesy Stone & Webster Journal

*Conowingo Hydro-Electric Development.*

WHAT was once the little town of Conowingo, Maryland, is now the bed of a lake which was formed when the Conowingo dam and power house were constructed across the Susquehanna River just two miles below the town. The Conowingo bridge on the main Philadelphia-Baltimore Pike was also flooded out and has been replaced by a new concrete bridge combined with and supported by the dam.

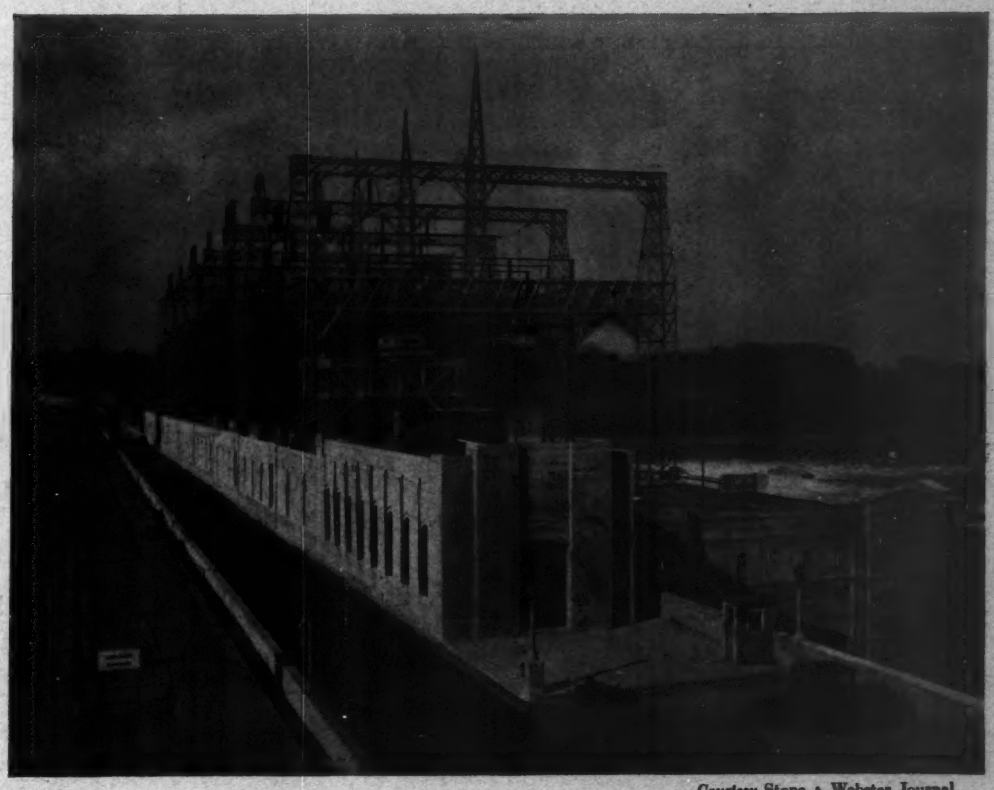
The dam, constructed of solid concrete, is 4,648 feet long including the power house headworks and the gate controlled spillway. It is imbedded in solid rock at an average depth of 96½ feet below the surface of the lake. The lake is fourteen miles long and over a mile wide at its maximum width. Constant level of the reservoir is maintained at the spillway, regardless of variation in volume of the water flow during wet seasons, by 50 movable steel gates surmounted by an overhanging crest.

Seven 54,000 H.P. water wheels and generators supply 378,000 of the 610,000 H.P. peak load now required by Philadelphia and interconnected districts. Transmission of the power is accomplished by means of two tower lines operating at 220,000 volts, each line consisting of three aluminum cables approximately one inch in diameter. A third line will be required when the ultimate capacity of 594,000 H.P., which the plant is expected to have, is realized.



*Model of the Philadelphia Electric Company's Conowingo Power Development in the Smithsonian Institution at Washington, D. C. At the top is shown a close up view of the Generator Room. The model of metal, wood and cardboard is five feet five inches high, four feet four inches long and two feet three inches wide. It was made to scale, one quarter inch to the foot, and shows all the essential features of the station. The entire operation of the huge hydro-electric plant is clearly visible.*

*View of Baltimore Pike over Dam.*



*Courtesy* Stone & Webster Journal.

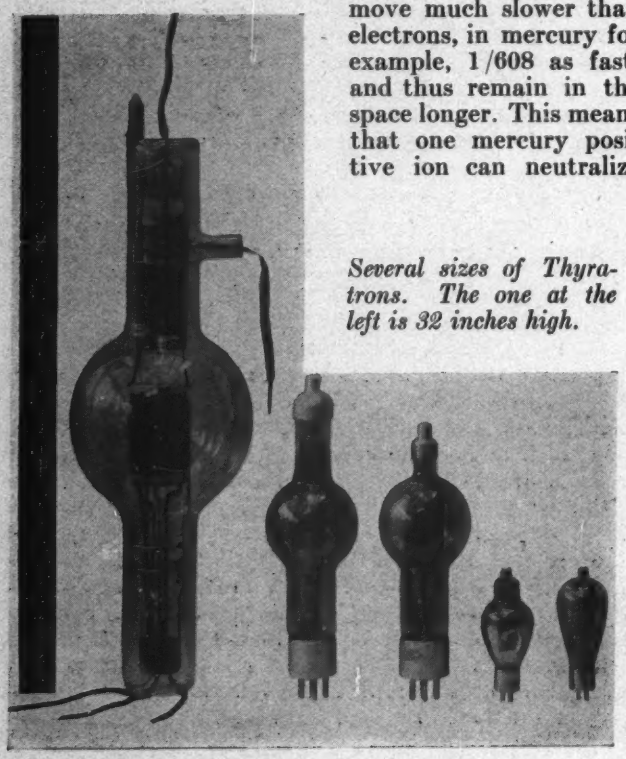
# The Thyratron

BY FRANK R. ELDER

*Research Laboratories, General Electric Company*

THE thyratron is a member of the three electrode vacuum tube family. Its name, (from the Greek, a door) is suggestive of its characteristics. In the ordinary pliotron the flow of electrons from cathode to anode is controllable at all times by the grid potential. There is thus a definite instantaneous relation between anode current and grid potential. Due to the presence of a low pressure of inert gas, purposely introduced, the pure electron discharge of the pliotron becomes an arc in the thyratron. We may thus briefly describe the thyratron as an electrostatically controlled arc rectifier. The grid, however, once having permitted the current to start, no longer has any control over it and can only regain control when the current has been stopped by some external means. The magnitude of the current is practically entirely fixed by the external circuit since the tube itself has only a few volts drop. As the grid determines the time current can start in each half cycle, if an alternating voltage is applied to the tube, the average value of the output current is fixed by the grid excitation.

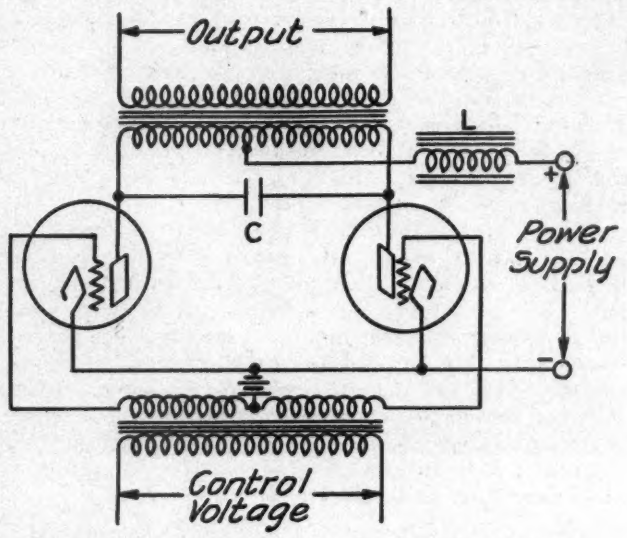
When a gas is bombarded by a stream of electrons it is observed that at a certain critical velocity, which is conveniently expressed in the equivalent volts necessary to produce the given velocity, a glow is produced in the gas and the current carrying capacity is greatly increased. This critical voltage is known as the ionization potential and is 10.4 volts for mercury vapor and 24.5 volts for helium, for example. The products of this bombardment are another electron and a positively charged atom or positive ion. It is readily seen that under proper conditions this action may become cumulative and thus lead to a self-sustaining discharge which is called an arc. Under a given electric field the positive ions being heavy move much slower than electrons, in mercury for example, 1/608 as fast, and thus remain in the space longer. This means that one mercury positive ion can neutralize the space charge of 608 electrons, thus a relatively small number of positive ions will permit large currents to flow in a discharge tube.



*Several sizes of Thyratrons. The one at the left is 32 inches high.*

## Positive Column

In an arc discharge the region of intense glow between anode and cathode is known as the positive column. In this positive column, experiment has shown that there exist about equal numbers of electrons and positive ions. Such a region has been called a plasma. Suppose now a wire is placed in the plasma and connected to a source of negative voltage. Electrons will be repelled from, and positive ions attracted to, the wire. There thus results a region about the wire which contains only positive ions, and if the density of ionization is low enough may be seen as a dark region about the wire. This has been called a sheath by Dr. Langmuir. Beyond the boundary of the sheath, which must be at the potential of the plasma, the wire has no further effect. The current to the wire is definitely limited by space charge and can be calculated from the appropriate formula.




*The "inverter" circuit which uses the thyratron to convert D.C. to A.C.—the inverse of rectification.*

It has been found that the thickness of the sheath increases with decrease in density of ionization and increases with increase of voltage applied to the wire. If then a grid composed of adjacent wires is placed in a plasma it is possible with suitable conditions of ionization and grid voltage to make the sheaths overlap, producing a barrier between anode and cathode, and thus preventing the discharge. This is the principle involved in the thyratron.

In the small sizes the tubes are not greatly unlike ordinary pliotrons in appearance. In the large sizes the departure is considerable as more leeway is available due to the fact that spacing only slightly increases the voltage drop.

The cathode may be a mercury pool or any kind of a thermionic cathode. A useful type of the latter is

(*Continued on page 138*)

# Modern Lamp Photometry

BY ORRICH H. BIGGS

*Lamp Engineering Department, Hygrade Lamp Company*

LAMP photometry is one of the subjects that is off the beaten path. The engineer and scientist find little to warrant an extensive development in so narrow a field. The layman's understanding of the subject is apt to be a faint recollection of a few school day experiments with a bar photometer. However, lamp photometry is of vital importance in its narrow field. It furnishes the lamp designer with his data and serves as a means of checking the quality of the lamps produced.

Measurements on an incandescent lamp are made for three variables, total light, current, and voltage. Voltage and current are ordinary electrical meter measurements. The voltage measurement must, however, be quite accurate as any variation in voltage will make four times as great a variation in light output. The total light measurement involves the measurement and summation of the light intensity in every direction. If the old bar photometer were used it would require not only a large number of measurements but also a laborious amount of work in reducing the data to a single answer. By various steps the work has been greatly simplified.

The spherical integrator is probably the most important improvement. By means of it, it is possible to make a single measurement of the total light output. The next big step was in the use of a photo-cell for a measuring instrument. This step was appreciated from the time of the discovery of the photo-electric effect but it had to wait for improvements in cells and amplifying equipment to make it practicable. It has now become general in its application. For the past two or three years, nearly every lamp factory has been using photo-electric photometers.

## Sphere Integrator

As noted above, the first significant improvement in the method of measuring total light output was the development of the sphere integrator. This device is a hollow sphere coated on the inside with a white matt surface. The lamp to be measured is put in the center of the enclosure and the measuring unit is at the surface of the sphere, screened from the direct rays of the lamp. The light from the lamp is so completely averaged by multiple cross reflection inside the enclosure that the detecting unit such as the photo-cell receives an average intensity of light. The sphere will average different types of light sources accurately but it is extremely difficult to construct.

Later developments for routine incandescent lamp photometry have indicated that the sphere is being superseded by the cube, the inaccuracies due to incorrect integration having been found to be very small. The advantages in using a cube are entirely constructional. To some it may seem peculiar that an integrator that is theoretically precise should be discarded for one that is admittedly less accurate. However, standard line incandescent lamps differ very little in their light distribution curves, so the integration error of a cube may be offset by using a similar lamp as standard, and there is no object in wasting effort and space on the sphere integrator.

The photo-cell, its filters and amplifier are much more likely to cause trouble. The photo-cells and their volt-ampere and sensitivity characteristics are well known so this discussion will be confined to photometric cells. In a photometer the total current coming from the cell is measured and is measured accurately. The current that is wanted is that caused by the light. Hence it is of paramount importance that the extraneous currents be small compared to the light current and also that they be very steady. These extraneous currents come from a number of sources and developments in the form of the cell and in the technique of manufacture have brought them down to a small value. Other applications of cells do not require such high standards of manufacture, hence when choosing cells for photometry one must be sure of using the right cell.

*Cubical Integrator. This type of integrator is superseding the older spherical one, which was slightly more accurate but which presented more mechanical difficulties.*

Cells are responsive to different parts of the spectrum. Cells of commercial manufacture cover the spectrum from ultra violet to infra red, not all in one cell, but in cells covering overlapping bands, so that with proper filters it is possible to approximate any sensitivity curve. In photometry the object is to duplicate the spectral sensitivity curve of the eye. The cells used generally required a filter, though cells of a given type do not differ greatly from one another and the filters necessary fall into a rather narrow group. In color correction practice each photometric establishment seems to have developed a technique and criterion of its own. It has been found satisfactory to photometer two lamps of about the same light output and widely different color with different filters.

(*Continued on page 132*)

# Elevators for Skyscrapers

BY E. W. YEARSLEY

*The Otis Elevator Company*

NEARLY a thousand feet above the street. That is the vertical rise of the ten highest speed elevators from the ground floor level to the eightieth floor in the Empire State Office Building in New York City. Floor 66 is the first stop after an express run of 800 feet, the elevators then serving 15 floors locally. A through trip by elevator back to earth from the eightieth floor requires only 50 seconds.

This upper main tower group of elevators has a rated speed of 1200 f.p.m., which is about two floors per second. Speed as high as this has never been previously used for elevators, yet it is not only safe but also comfortable to ride in these cars where there is no sensation of high speed. Above the main tower, there is a super-structure, provided with a group of two shuttle elevators, surmounted by a mooring mast, the top of which is 1248 feet above Fifth Avenue. This also has its elevator.

From 20 to 25 thousand people will populate this building, working on its more than two million square feet of net floor area. Sixty-seven automatic elevators operating in seven main groups, each bank serving its zone of floors, with the load capacities per elevator ranging from 3500 to 4000 pounds and with speeds of from 700 to 1200 f.p.m., are required.

## Automatic Elevators

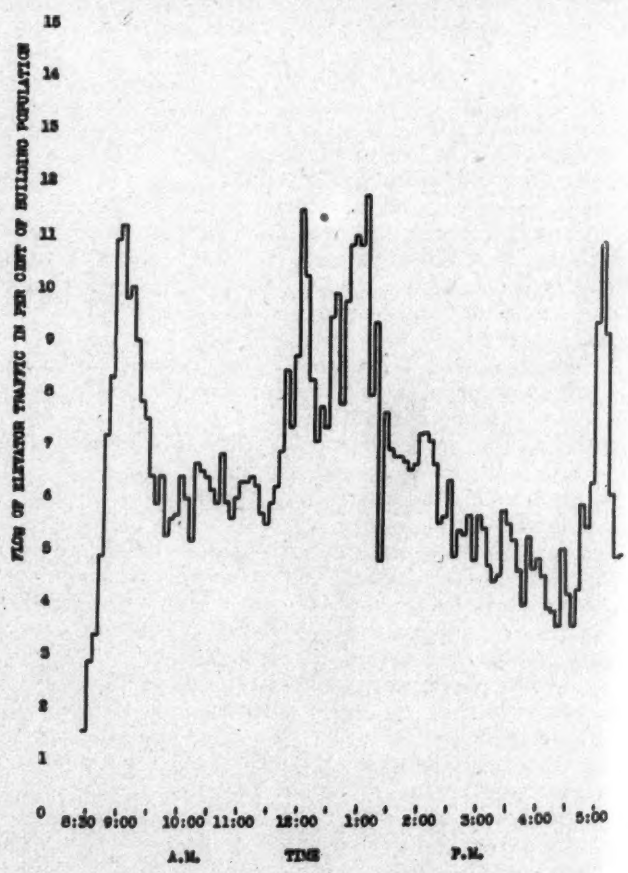
In order to consume as little time as possible for the various necessary operations and so reduce the typical trip time, automatic operation is employed as far as possible for high rise, high speed elevators particularly. Such operation is, in fact, becoming standard for practically all the elevators for what may be termed "intensive service buildings" and all the elevators in the Empire State Building have this automatic operation which is generally referred to as "automatic signal control." With this control, the stopping of the elevators is automatically set by momentarily pressing push buttons in halls and cars. Two "signal" buttons, one for Up and one for Down are located in each hallway and momentary pressure sets the stop so that the first car available will automatically stop, level and open its doors after indicating its approach by a light over the door and also, in the new buildings, by the tap of a bell as the light is illuminated.

When the operation is manual, these hall buttons only give a signal to the operator who may, or may not, stop the car with more or less effective operation if the elevator speed is below 700 f.p.m.

Manual operation at higher speeds is practically impossible for the reason that the operator cannot properly gauge the position of the car in the hatchway. With automatic operation a set of buttons in each car, one for each floor served, will be momentarily pressed by the operator, according to the directions of passengers as to the floors at which they want to alight.

After the passenger transfer at the landing has been completed, the attendant in the car moves a small lever, thus initiating the door closing, after which the hatchway door is closed and locked and the car door is closed, the elevator then automatically accelerating and proceeding until close to the first stop set by either car or hall buttons, when it is automatically slowed down and brought to the landing without delay and leveled as the doors open, the car and floor remaining level during the entire time that passengers enter and leave. This system, which is adaptable to any elevator speed, requires the minimum time for all operations. An attendant is necessary to initiate the door closing if no time is to be wasted, because the number of passengers transferring at the landing varies with chance. It is also desirable to have an attendant for the purpose of policing the car and assisting, as far as possible, in the rapid movement of passengers at landings, which is facilitated by the level landing which eliminates tripping hazard and the necessity for passengers to watch their steps.

Automatic elevators give the maximum amount of service for the minimum amount of hall and hatchway space occupied. For intensive service their cost over manual elevators is very much more than compensated by the decreased cost of the elevator service and the additional rentable space obtained. Considering, again, the high rise elevators in the tower of the Empire State Building, and comparing them with manually operated 600 f.p.m. elevators such as are in use in the earlier tower buildings, these elevators have an increase




*Typical flow of elevator traffic in a fifty story diversified tenancy office building in the Grand Central zone of New York City.*

in service of about 74 per cent and therefore, for a given amount of service only occupy 58 per cent of the space in the building that the best elevators available up to about 10 years ago would occupy. This is on the basis of safe service with full door interlocks.

All modern high speed elevators employ a slow speed D.C. motor with a friction driving sheave and the electro-mechanical brake drum integral with the motor armature. Because of their extremely slow speed which is usually from 60 to 150 r.p.m. and the necessity for their proper control in acceleration and particularly in retardation, these elevator motors must be of the D.C. current shunt type.

When multi-voltage control is used, the voltage adjustment for acceleration and retardation is obtained from a direct current generator with variable field, which is direct connected to a practically constant speed induction motor or to a direct current motor, depending upon the kind of supply. Such a control is inherently smooth so that no shocks are felt with high acceleration and retardation and the elevator is quickly brought to a very low speed from which a level stop may be obtained. Acceleration and retardation are high, particularly as compared with those of horizontal transportation, but they are so smooth that passengers are not inconvenienced and the operation is so constant that the objectionable sensations of the older elevators operated by rheostatic control are avoided.

By the use of solid doors on the cars, the psychological effect of speed is eliminated and passengers do not know that they are riding at high speeds. There is a slight sensation noticeable in the ears, due to change in air pressure with level, but as this is automatically corrected by the passengers instinctively swallowing, it is not seriously objectionable and, in fact, most passengers do not notice it.

## Speed Requirements

Although 1200 f.p.m. is now the highest elevator speed, there will be speeds of probably 1500 f.p.m. or more, if considerably higher buildings are built, as now seems likely. Speed, of course, becomes more advantageous the longer the runs and therefore high speed becomes essential with high rise and is most effective the fewer the stops made. An elevator will handle the maximum number of people in unit time when making terminal stops only.

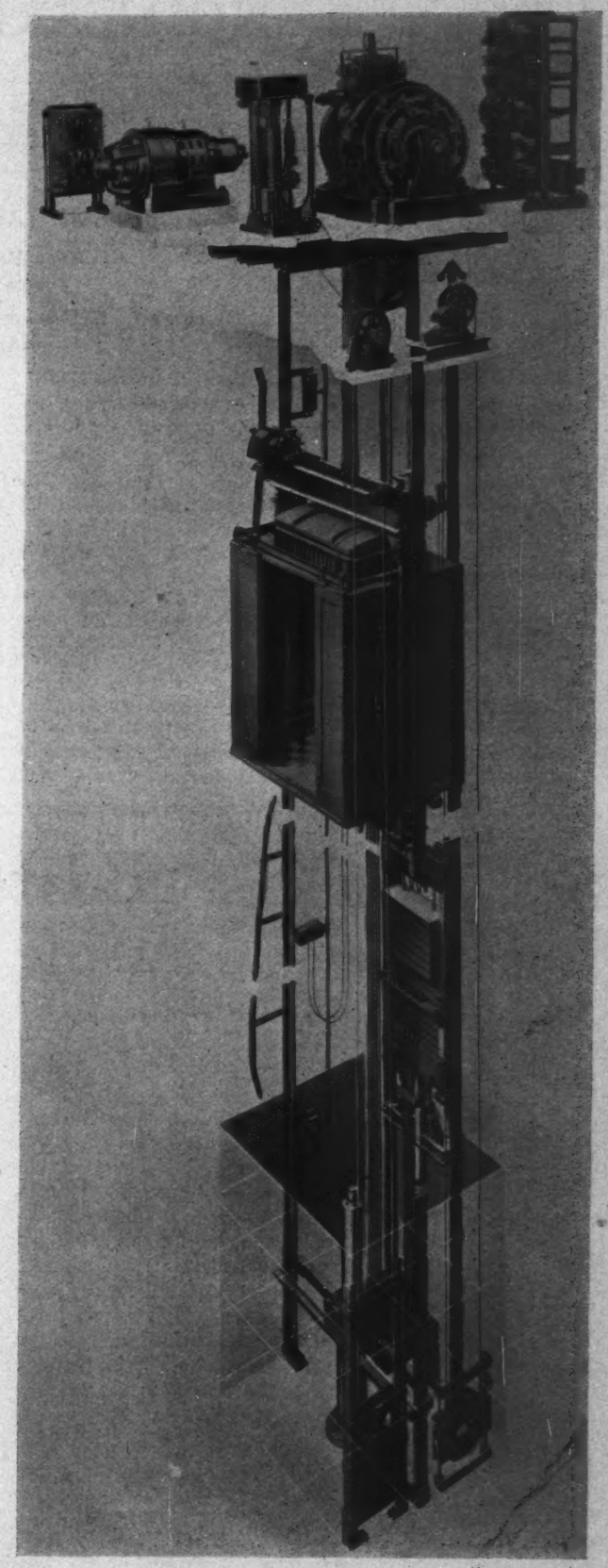
The problem of accurate operation without waste of time and prompt and accurate leveling has received careful engineering attention. It has been solved without the introduction of delicate or uncertain devices and so that the minimum maintenance is required. All the controlling apparatus is located in the penthouse and the selector which controls the automatic operation is directly driven by the car and therefore always maintains its proper position with regard to the location of the car. Magnet controlling devices are employed which do not make use of dashpots or other uncertain operating devices.

Another problem that has been satisfactorily solved recently is that of power operation of the car and hatchway doors. An electric engine mounted on the car structure operates all doors, requiring less than a second for the movement of the door in opening or closing for 42 inch door openings in office buildings.

Elevators are located in the central core of a building where the space is least valuable. They should fit into the standard steel structure of office buildings, the bay of which is about 19 feet long for the most economical plan. Such a bay will take two modern high speed elevators, which may have capacities from 2500 to 4000 pounds.

Elevators must be arranged in groups running to different heights and generally speaking, there should be as many groups as will permit a satisfactory in-

*(Continued on page 134)*



*View of typical elevator installation. The method of attaching the car to cables, hoist, and counterbalance is shown.*

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# Editorials

## Michael Faraday

One hundred years ago Michael Faraday discovered the phenomenon of induction which has played a very large part in building up the modern electrical industry. It is fitting that this, the last issue of the academic year, should be devoted to the exposition of some of the phases of electricity as applied to modern life.

It is interesting to speculate, among other things, on how electricity has bound the earth more closely together. A hundred years ago it was possible for Faraday and Henry, one in England and the other in America, to discover the identical phenomenon and still remain in ignorance of each other's work for quite a period of time. Today, the announcement of an important discovery would be flashed by electricity to all corners of the earth and within comparatively few hours would be universally known.

This is but one aspect of electricity's contribution to our civilization. There are many more already in use and still more are yet in the experimental stage. What the future holds is well-nigh impossible to prophesy.

## A Double Opportunity

It is unfortunate that human nature is so constituted that four years in college is not enough time to assimilate both a thorough technical training and a thorough grounding in the liberal subjects. The student who elects the former must, while at school, neglect the latter; while the one preferring the liberal studies must remain ignorant of the technical, scientific subjects.

Both are essential to our modern civilization. Our mechanistic age demands men of the highest type, with the training which will equip them to control and direct it. This calls for the engineer. The complex and ever more closely bound relations of one people with another and their often conflicting aims, require the utmost in broad human understanding, the ability to see into the future and to act accordingly. This calls for the liberally trained man. The individual who would equip himself for leadership must have both of these attributes. He must understand both the mechanical and social aspects of his environment.

In this, we believe, the technically trained man has one advantage if he will take it. It is relatively easier to pursue the liberal studies by oneself than it is to gain a real technical knowledge without help. It is next to impossible to start into the fields of science without any grounding in mathematics and mechanics and get any real understanding of them. On the other hand, it is possible to study literature, the arts

from an appreciative point of view, philosophy, sociology, et al., if the will to do so is there. The engineer can be aided in his study of them by his analytical modes of thought developed in meeting and solving technical problems. He can more quickly digest his reading, following the writer's thought and philosophy with more facility.

The engineer thus faces a double opportunity—and a challenge. He can, if he desires, acquire a more universal outlook upon life than can most individuals because he can master two fundamental aspects of it, the physical and the social. If he does, he will be in the finest of positions to intelligently take responsibility and help to guide his community wisely. This is his opportunity. But he must take heed that the machine which he has created works for the benefit and not the detriment of mankind. This is his challenge and the engineer who meets it will attain a place of respect among his fellows.

Unfortunately, all too few engineering students have the inclination or the will to accept the opportunity. Too many are smugly satisfied with the conviction that the engineer is the salt of the earth. It is true that engineers are being given more and more control but those who are receiving it have more than a good technical training—they also have an understanding of human nature and human relationships.

## New Obligations

Modern science contains within itself the elements necessary to destroy civilization as we know it or to carry it to new and transcendent heights, making it the first civilization of history which has not succumbed to forces of decay and sunk gradually into the dust from which it arose. Man, in his blind, undirected search for knowledge, has until recently neglected this fact, with the result that we have today a life rapidly increasing in its complexity and speed to which man's nervous and moral fibres are but ill adapted. The spread of public education has taught man to read and write, but it has not taught him to use his new tools. On the other hand, the sciences of biology and medicine are making rapid strides in the cure and prevention of disease. Psychology is finding out new facts about the mind and its inner workings.

What is to be the result? Will we become long-lived dullards and moral weaklings? The answer rests with the scientist and the engineer. With them lies the answer to the question of nervous and moral development keeping pace with knowledge and discovery. They must come out of their laboratories and workshops to take a hand in the affairs of the world, to supplant incompetence wherever found. They can supply the materials to make a great civilization; they must also superintend their use.

## Commonplace Wonders

Technology's unusual reputation as an engineering school is due largely to the great amount of modern equipment it uses in its instruction. It is strange that more interest is not taken in this equipment by the students. Even on such occasions as Open House those acting as guides for friends and families like to assume an air of easy indifference to the wonders to be seen. Such things as integraphs, triple expansion Corliss engines, and wind tunnels are commonplace. But it is not familiarity which breeds contempt. It is a sort of half knowledge and a feeling that things passed daily cannot possibly be of as much importance as the quiz in Applied.

The wonder-struck attitude of visitors should serve to show that we live and work in a veritable museum. By making fuller use of the equipment with which we come in contact in laboratories and by cultivating a healthy curiosity about the equipment we do not ordinarily study, we can broaden our outlook on engineering immensely. A free hour spent in trying to find something new about something old or commonplace is well worth the time.

## Staff Elections

The Managing Board of *The Tech Engineering News* announces the following elections; J. Godfrey Borger and Walter F.. Read, Assistant Advertising Managers; Frank M. Hartz, Assistant Treasurer; James B. Wadhams, Assistant Circulation Manager; Ralph P. Ranger and David W. Bernstein, Business Staff; Joseph Doleda and Joseph L. Seligman Jr., Editorial Staff.

# Copernicus

### 1473-1543

The eventual overthrow of Ptolemy's geocentric theory of the universe was primarily due to Copernicus, the brilliant and versatile Polish astronomer. His life is a record of study and thought throughout, starting with his work in mathematics and the fine arts at the University of Krakow. Later he went to Bologna to study canon law, varying his studies by attending lectures on astronomy. He then entered the medical school at Padua having taken a doctor's degree in law at Ferrara. After acting as his uncle's physician for several years he retired to Frauenburg and vigorously attended to his capitular duties. Although he never took orders in the Church, he acted in many semi-official religious offices. His medical skill, always at the service of the poor, was frequently in demand by the rich, and he devised a scheme for the reform of the currency. Amid all these occupations he found time to elaborate a new system of astronomy, the adoption of which changed fundamentally man's outlook on the universe.

This man deserves our attention because he was bold enough to challenge the truth of the writings of the renowned Ptolemy, not to mention all the philosophers, popes and bishops who regarded the earth as the center of the universe. Copernicus rejected Ptolemy's theory of the heavens and argued that the sun was the center of the universe around which all the planets, including the earth, moved. Ptolemy's stumbling block in accepting the idea of a moving earth had been the likelihood of bodies on its surface being instantly blown off it if the earth spun around on its axis every twenty-four hours. Copernicus showed that this objection was purely imaginary and that the atmosphere and all loose objects were carried with the earth in its rotation. He made unremitting observations of the sun, moon and planets with the scanty instrumental means at his disposal and then used his fine mathematical training in drawing his conclusions. One of his great published works was on plane and spherical trigonometry. His genius appears in the fact that he grasped the truth centuries before means were at hand for direct proof.

The demolition of a scientific system which has been consecrated by a thousand years of university acceptance is a serious matter, and Copernicus hesitated a long time about making his theory public. It was hard to decide whether to publish his great work or to imitate the Pythagoreans, who transmitted the mysteries of their philosophy only orally to their disciples for fear of exposing themselves to the contempt of the multitude. His friends finally prevailed upon him to publish his famous book of observations and conclusions, "On the Revolutions of the Celestial Orbs." The first copy of the printed book was brought to him on his death bed but he died happily unconscious that his fine Epistle, in which he had dedicated his life's work to Paul III, was marred in its effect by an anonymous preface, slipped in by Osiander, with a view to disarming prejudice against the work by insisting upon the purely hypothetical character of the reasonings introduced. His heliocentric planetary theory was not accepted at once, not even by the astronomers. The hold of tradition and authority was too strong to be broken suddenly. Galileo was a staunch supporter of the Copernican doctrine, but was forced to recant publicly everything he had believed and taught, because of the opposition of the Church. Gradually men were won over to the truth and now the accepted theory stands as an everlasting monument to Copernicus.

## PROFESSOR FREDERICK S. WOODS

*Head of the Department of Mathematics*

The life of a mathematician is thought of as an uneventful one from the standpoint of being able to conduct interesting experiments in the laboratories with the use of delicate instruments, or of being able to carry on extensive research in the outside realms of science. This unfortunate position of the mathematician, if it may be called such, is greatly offset by the fact that he finds himself in possession of the very basis of science, for without a thorough knowledge of mathematics the physicist, the chemist, or the engineer would be greatly handicapped in their research work which gives rise to so many difficult mathematical problems. As a mathematician, Professor Woods has spent an interesting and eventful life in aiding engineers to solve their problems.

Professor Woods was born in 1864 in Munson, Massachusetts. After completing his earlier training he attended Wesleyan University, graduated in 1885 with the degree of A.B. and then received his A.M. degree three years later. During the year immediately following his graduation he served as an assistant in physics and astronomy at the University, and then taught mathematics for four years in Genesee Wesleyan Seminary at Lima, New York. In January of 1890 he came to the Institute as an instructor in mathematics and was granted leave from 1891 to 1894 to study in Germany, where he took the degree of Ph.D. under Professor Felix Klein in Gottingen. Professor Woods then returned to the Institute and has been actively associated with the department ever since. He was made Professor in 1906 and head of the department in 1930.

Professor Woods' early scientific interests led him into the field of geometry. He became interested primarily in non-Euclidean geometry at a time when the subject was not very well known. Included among his articles dealing with this phase of mathematics are a section on Non-Euclidean Geometry in "Monographs of Modern Mathematics" and a series of lectures on Forms of Non-Euclidean Space, which appeared in the "Boston Colloquium of the American Mathematical Society." Besides these, Professor Woods has written a book on "Higher Geometry" and also a book on "Advanced Calculus." This last book embodies the work given for many years to graduate students as an introduction to advanced mathematical work.

In addition to his work along these lines, Professor Woods has collaborated with Professor Bailey in dealing with questions of undergraduate instruction in mathematics and in developing and improving the required courses at the Institute. This has resulted in various Woods and Bailey texts which, although written and frequently revised primarily for Institute needs, have found large use elsewhere. With the use of these texts the Institute has established a unified course in mathematics, thus breaking away from the traditional college courses. At the time when Professor Woods first came to the Institute the study of Calculus was not begun until the middle of the second year whereas now, it is begun immediately upon entrance.

Professor Woods is a Fellow of the American Academy of Arts and Sciences, a Fellow of the American Association for the Advancement of Science, a member of the American Mathematical Society, a member of the Mathematical Association of America, and a member of the Société Mathematique de France.

As head of the department his aim is to give the most effective under-graduate instruction possible and at the same time to maintain and advance the position which the department of mathematics has already attained as one of the leaders in the country for mathematical research and study.

# Departmental Notes

*Department of Aeronautical Engineering*

The academic year of 1930-31 has been a very active one in the Department of Aeronautical Engineering. For the first time several senior options have been offered the students so that they could select in a broad way between several different fields. The four choices offered were in the specialties of Advanced Airplane Design, Engine Design, Theoretical Aerodynamics and Research, and the Commercial Operation of Aircraft, which last option includes an elementary course in the subject of Meteorology. It is hoped that by thus broadening the scholastic attainments of the students that an increased opportunity for employment will be available to the class as a whole upon graduation.

In the lower grades, the major change has been one in the summer school of seven weeks' length which follows the Sophomore year and which will be instituted this summer. The former courses of Forging, Foundry, Pattern Making, Machine Tool, and a single week of airplane shop work are being replaced by a much longer course on airplane shop work and another course of visiting various basic factories whose processes are allied to airplane production and which also includes a week's residence in Hartford, Connecticut, visiting the Pratt & Whitney engine factory and the Vought airplane factory.

There has been more research conducted during the past year than for a number of years previously. A new type of research mechanism in aerodynamic work has been developed and is practically completed in the Steam Laboratory of Building 3. This apparatus, which it is hoped will give superior results in some fields of research to those attempted by the wind tunnel, consists of a cable way down which models of aerodynamic shapes are coasted with rather complicated mechanism for measuring resistances, velocities, for compensating for wire sag, and so on. The wind tunnels have also been active in thesis work and departmental investigations, much work having been done in the general field of airship aerodynamics. A great deal of important work has also been carried out in the structural laboratories in the field of metal construction of aircraft. This has been of a fundamental nature as to shears and stresses in unit plates and has attracted much attention throughout the industry.

The Engine Laboratory has likewise carried on a great deal of research work on the Diesel engine and toward the development of a high speed, high accuracy internal combustion indicator mechanism. In the field of mathematical aerodynamics much has been done toward elaborating the theory of wing flutter of airplanes.

An exceptional number of investigations of a shorter nature have also been carried out in practically every field of aeronautics by the undergraduate and graduate thesis workers.

Little has been added in the way of equipment during the past year with the exception of the coasting mechanism described above. The staff has, however, been enlarged by the addition of Professor Rauscher who had previously been an instructor before entering the field of practical airplane design several years ago. Dr. Heinrich Peters was added to the research staff, coming from the University of Göttingen in Germany. Miss Hilda Lyon, a graduate of Cambridge University and with a number of years' experience in airship work in England, has been carrying on research here as a graduate student for the past year and will continue next year as an instructor on the aerodynamic staff.

# Recent Books

MODERN DIESEL ENGINE PRACTICE. By Orville Adams. The Henley Publishing Co., New York. Illustrated. Price $6.00

It should be immediately recognized that this book is one dealing with Diesel Engine Practice and not fundamentals. The details of technical design and fundamental principles are left for another author.

On the surface, the material seems to be disorganized. It is apparent that the author has accumulated a rich store of operating and consulting experience, and has printed it much in the same order as it existed in his records. Much of the material must have been supplied directly from the literature of certain engine manufacturers and from the standards of the Diesel Engine Manufacturers' Association.

There has been very little effort to combine all of the information on one subject to one section of the book. Material on lubrication for instance may be found in numerous places. The result is a duplication and inaccessibility of the subject matter. It will be very difficult for anyone not familiar with the subject to tie various statements from different sections into a harmonious whole.

The inaccessibility and the lack of fundamentals will make the book of limited use to students. Even an operator, a mechanic, or an engineer could profit from an understanding of the fundamentals before reading this book.

Of course the construction and performance of the engines cited cannot be intelligently discussed in regard to their excellence in attaining the fundamental requirements.

Probably much of the material was supplied by manufacturers and obviously nothing can be said in regard to the relative value of different engines. A frank constructive analysis of existing engines by an authority would be of benefit to all and especially to those manufacturers who are now bringing up the rear of the profession.

Only a very small per cent of the total number of Diesels on the market have been described or even mentioned. What determines the requisites for inclusion in the limited array, the excellence of the engine, or the experience of the author is not evident.

Notwithstanding the difficulties, the book offers a host of ideas new to the public and many of them new to the trade. It is a great improvement over the few books available in the past.

There is a tremendous amount of interest in Diesels springing up in the United States. There is a crying demand for good books on the subject and especially those including descriptions of the high speed types.

Due to the general extent of the interest, this practical, not too technical work should do much to remove the Diesel engine from the plane of superstition and mystery in which it has remained so long. The engineer and operator will find material on practical operation which cannot be found in a text on fundamentals.

The introduction to the high speed Diesel giving its relation to the general field of internal combustion engines is one of the best offered in any text up to the present time.

In the past, there has been a tendency to condemn the whole Diesel principle because of failures in structural parts of the engine or its auxiliaries. A practical book of this nature will do much to correct the misconception of the Diesel. It also points out certain power demands which can best be served by the Diesel. In general, it is a good contribution to the meagre store of available Diesel literature which exists in the English language.

Myron S. Huckle.

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**Locomotive Main Crankpins** are being subjected to enormous thrusts in modern locomotives. This results in higher maintenance than was formerly necessary. To relieve the thrust of individual pins, locomotives having three and four cylinders are popular with many lines in England and on the Continent.

In America, where locomotives are far more powerful than elsewhere, multi-cylinder designs are generally considered too complicated, although certain roads use three cylinder locomotives. A system known as a tandem or articulated main rod has been developed to meet the situation. The back end of the connecting rod is forked and the front end of the parallel bar to the driver behind the main driver fits into the fork. This rod is termed "main rod No. 2" although the motion is the same as that of the normal parallel or side rod. The two connecting rods are connected by a steel bushing, which surrounds the main crankpin, and relieves it of the thrust transmitted to the back drivers. It is said that on an eight-coupled locomotive, the main pin takes only 75% of the thrust; on a ten coupled, 60% and on a twelve-coupled, 50% of the thrust.

**Coal Passers** and stokers are part of the equipment of most of the very large locomotives in America, but their use in England has thus far been limited. However, a passer differing radically from any of those used in America has been applied to one of several 2-6-0 + 0-6-2 Garratt articulateds recently delivered in England. Garratt locomotives are double-enders, and about half the time must run with the cab end leading. The reduction of the coal dust blown back into the cab is one of the features of the passer, which need not be considered on American locomotives.

The bunker is in the form of a frustrum of a cone, the top of which is horizontal, the larger end forward. The axis is therefore somewhat inclined, and the bottom has sufficient forward slope to cause the coal to run down to the doors, of which several are provided in the front end. The bunker may be rotated by hand through suitable gearing, or by a small engine. A few turns bring enough coal forward, and as these take only one to two minutes, the fireman's time is not taken up by the device. Several doors are provided in the top to fill it.

# Modern Lamp Photometry

(*Continued from page 125*)

This will give a filter combination of minimum error. The error introduced by the cell without filters is not extremely large. In a recent measurement, the lamp voltage was reduced by forty per cent and the cell reading was in error only four per cent, although the color of the lamp on sixty per cent of its rated volts was a decided reddish yellow.

## Cell Improvement

The overall sensitivity cells, that is, those measuring the current per lumen, have been improved considerably. A number of years ago, when a potassium hydride, barium or sodium photo-cell had been corrected to human eye sensitivity the current per lumen was very small, some few parts of a microampere. Today, with the caesium cell the loss in color correction is much less and the current is the order of several microamperes.

Microamperes are still rather small for our regular forms of meters, so a photo-electric photometer requires a direct current amplifier unit. The cell and amplifier unit are designed to give sensitive stable performance on the weakest intensities of light measured. The higher intensities are cut down by a shutter.

There are at present three general types of D.C. amplifier units. In each arrangement the characteristics of the cell and amplifier have been eliminated from the performance of the photometer to a different degree. In the first type the distortion of the amplifier enters directly with the response of the cell. In the second the amplifier unit merely serves as high sensitivity galvanometer for a potentiometer. The cell with either of these arrangements must have the same sensitivity curve as the human eye and must be linear in its response. The third type is in a class by itself. It is semi-mechanical, as the cell takes the place of the human eye in the old visual arrangement and is called upon only to establish a balance between the light from the unknown and that of the standard. The measurements are made from the displacement of the standard lamp. This method eliminates the necessity of linear response of the cell. It has not been as much used as the other types, because of mechanical complications.

The first type of amplifier has the advantage of being easy to construct and is also quite sensitive. We have used it with a photo-cell to measure some very weak radiations. The grid current and plate current characteristics enter into the performance of the cell, and as the performance of the whole unit, cell and amplifier, is generally corrected by color filters it may be necessary to change filters when the amplifier tube is changed, using the same cell. Also, this type of amplifier is very sensitive to any change in battery voltages. One advantage of this method is that it is direct reading, all others requiring some balancing. The second general type is a bridge arrangement. It is stable and very sensitive and in addition, as pointed out before, it does not affect the cell performance. The bridge arrangement tends to minimize the effect of battery fluctuations and is much more suitable for operation from a rectifier and filter circuit than is the single tube unit. The use of a potentiometer to measure the photo-electric current also helps to keep out distorting variables. It might be well to note that there are a great many variations and combinations possible with these two circuits and each arrangement has its own advantages. With reasonable care in construction and proper choice of variables this bridge circuit can be run very satisfactorily on alternating current.

## Vacuum Tubes

The vacuum tubes used in either amplifier must be solidly constructed and must have a low, stable grid current. However, it is well to note that we have had very few tubes of regular manufacture that could not be used. It is a strange thing that with as much interest as there is in photo-cells there has been so little activity among tube designers in developing a line of suitable direct current amplifier tubes. The worst defect in a radio tube used as a direct current amplifier is grid current. The photo-cell current and grid current pass through the same grid leak and thus both affect the potential of the grid. The grid current comes from a number of different sources such as leakage between elements, ionization of the gas, emission velocity of electrons, and secondary emission of the plate. Most of these sources of current are small but they all depend on different variables and go to make up a grid current that is highly erratic. Hence the grid current of the tube must be much smaller than the cell current to obtain stable operation of the combination. This factor is quite fundamental in the design of direct current amplifiers and it would save the photo-cell experimenter a great deal of trouble if he would consider it.

Though it is possible to use radio tubes of regular manufacture the grid leak is much more critical and requires special and expensive wire wound resistances, and all connections in and around the grid leak must be well insulated for stable performance. The higher the grid leak resistance the greater is the magnification of the cell current, but also the higher the grid leak resistance the more serious is the leakage resistance across surfaces and through insulations that parallel the grid leak. These all introduce erratic variables more or less dependent on the temperature and humidity and limit the practical value of grid leak resistance to about fifteen to thirty megohms. The photo-cell itself must, as pointed out before, be practically free from leakage. The rest of the circuit is rather insensitive and subject only to mechanical difficulties.

The amplifier unit as noted above has been made to operate quite satisfactorily on alternating current, in fact the whole photometer has been used on such a supply. This has become possible through an A.C. voltage regulator that was developed a few years ago. The ordinary one hundred ten volt current supply is not steady enough, particularly in a manufacturing establishment, to use even the best compensated bridge on a rectifier circuit. This regulator was first used to control the rectifier circuit supply and later was used to regulate the voltage of the lamp supply. Since voltage affects the light output tremendously, a one per cent change in voltage amounting to a four per cent change in light output, it is necessary to adjust the voltage very closely. Also the photo-electric cell meter follows the light fluctuations directly and this unsteadiness not only introduces an error but gives the operator a feeling of uncertainty. With the older

# The crime wave, too, strikes a breakwater

*An alarm! Headquarters radios it to cruising cars.*

**Police Radio is "joining the force" in many a city—acting as a breakwater in checking the surge of criminal activity . . . The apparatus the police are using comes out of the telephone workshop. It is logical that Western Electric should make the equipment, drawing on a fifty-year experience as manufacturer of telephones for the Bell System . . . Serving this vast organization is a huge responsibility. Carrying it out means keeping an open mind on new methods of manufacture, new sources of supply, new channels of distribution. It means welcoming and taking full advantage of every worth-while aid that modern science offers**

*This engineer's "precinct" is a laboratory.*

*Caught—because the radio saved precious minutes.*

## Western Electric

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SINCE 1882 FOR THE BELL SYSTEM

visual method the error would be as large but not as obvious. The regulator is required to do a real job as it must cut the normal line fluctuation of one or two per cent down to five to ten hundredths of one per cent.

There is a real need for a completely A.C. photometer when it is considered that each D.C. photometer requires its own battery or generator. The initial cost of a large high volt battery or closely regulated generator is large and there is considerable maintenance expense. Hence we have assembled the various ideas as discussed above into a small A.C. photometer. This device is built to handle lamps up to 250 watts. It has proved quite rapid in operation, its speed being 100 lamps an hour. The layout of parts being made with speed and convenience in mind, we found it best to depart from the conventional form. The integrator is a cube mounted in the desk with a foot-operated lamp door. The lamp voltage adjustments, potentiometer adjustments and meters are all mounted on the top of the desk.

This arrangement of parts was chosen to give the operator a minimum waste of motion. The machine in its two years operation has given little trouble. It has been used as a routine sample check on about 90 per cent of the lamps manufactured. During our daily intercheck between photometers we have found this outfit to be fully as accurate as the others.

## Elevators

*(Continued from page 127)*

terval (average time between elevators to answer calls) since the smaller the number of floors served per group, the more traffic handling capacity in unit time will be obtained per elevator. For very high towers groups of from 8 to 10 elevators are employed for securing the proper interval which should, for the best service, not be more than from 20 to 25 seconds.

### Multiple Systems

Since it is so important to reduce to a minimum the space in the building occupied by the elevators, various systems have been proposed, the first of which will be referred to as the "multiple deck" system. Assuming that an elevator car has two compartments which are separated by a vertical distance equal to a standard floor height, then by stopping at two floors simultaneously, the number of possible stops is half that of a single deck elevator serving the same number of floors. If, therefore, a single deck elevator is replaced by a double deck elevator, the traffic handling capacity in a given time may be more than doubled.

The platform area is, of course, doubled without any increase in hatchway or hall space. The distances are run in the same time as by the single deck elevator. Passenger transfer can take place at two floors simultaneously. Finally, the number of actual stops made will usually be reduced from that made by single deck elevators. Obviously the round-trip time for such an elevator under maximum suitable passenger loading will be less than that of the single deck elevator and as it will carry twice as many passengers, the service will be more than doubled. Still further increase in traffic handling capacity for space occupied will result from triple deck elevators making three stops simultaneously.

The effect of the multiple deck system is similar to that of adding cars to a train, although there is a limit to the number of cars that can be employed. With either two or three deck cars, however, there is only the question of difference in lower terminal of a standard floor height. For the double deck cars, there are two lower terminals, one of which may be at ground level and the other about 11 feet below it. The triple deck elevator may have another terminal a floor above the ground. These lower terminal floors will be connected by Up and-Down escalator service and are particularly beneficial in providing increased space suitable for stores and restaurants, which is almost as desirable as space on the ground floor.

Double deck elevators are now being installed for the tower service of a new building in New York City. They are of the automatic type described above. This is the first installation of elevators of this type and the effect of this service will be carefully observed.

Another system for increasing handling capacity and reducing space is that which proposes to operate two or more elevators in the same hatchway. In the case of two elevators, there would be two lower levels, the car using the upper level serving a zone of floors immediately above that served by the car using the lower level. The upper car must leave before the lower car and the lower car must arrive before the upper car at the lower terminal. Automatic devices must be used to keep the cars separated sufficiently. Additional mechanical safety devices are required to prevent collision. Additional space around the platform is also required because the hoisting and compensating ropes of one car must pass by the other and the traveling cables of one car must operate between the car platform and the hatchway wall. This system requires as many elevator machines as there are elevators, while the multiple deck system uses a single elevator machine for each two or three compartment car.

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### Advantages for Both Systems

Although, under certain conditions, there will be some advantage for either of the above systems, it may be generally stated that the two systems, double deck and two elevators in the same hatchway, operating in a building, will require about the same amount of space for a given amount of elevator service. Conclusions as to the adaptability of these systems to a given building can only be reached after actually incorporating the necessary elevators in the building plan and determining the cost of elevator service, the interval, and the value of the rentable space in each case.

It is assumed that where the two elevators run in the single hatchway they operate as express and local elevators, the top serving the upper, which may be called the express floors, and the bottom serving the lower, which might be called the local floors. If the two elevators operating in the same hatchway would each serve all the floors and therefore each be what might be called "local elevators," then their traffic handling capacity for space occupied would be greatly reduced. This fact is mentioned because proposals have been made to operate two elevators in the same hatchway in this impractical way. This system is not properly applicable to serving an entire zone of floors locally, but the double deck system is well adapted to such service.

The tower of the new building at No. 1 Wall Street has been arranged so that while operating at present with a single elevator in each hatchway, a second elevator in each hatchway may be readily installed. This arrangement was made so that, if, in the future, the service requirements of this tower should considerably increase, due to high density of population, which seems likely because of the advantageous location of this building, satisfactory elevator service can be obtained.

Still another system has been employed to some extent and its use will probably be extended. This is similar to the express and local arrangement used in the New York Subways. Express elevators will make rather widely separated stops at so-called "plaza" floors. Local elevators will operate one above the other in the same hatchway to serve the floors between the express stops. This system has the objection of requiring all passengers except those occupying the "plaza" floors to change cars, but as it has considerable economic advantages, will probably be used where service of this type would be considered reasonably satisfactory.

### *Correction*

April Issue. "*Corrosion and Heat Resisting Steels*," by F. J. McNiff. Page 102, col. 2, par. 5, line 11, read "under .07%." Page 104, col. 1, line 4, read "less than .07%;" col. 2, line 3, read "until 25.00% is added.


*Announcement*

The October Issue of

**T. E. N.**

will appear on

*REGISTRATION DAY*

*September 28*

1 A 5-ton truck breaks the Mathews Hydrant. No water gushes up; it cannot leak.

2 The head is rarely damaged; can be used again. It is removed to get at the lower part.

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# Luminous Tubes

(*Continued from page 121*)

either to operate or start it. However, its light was faint and inefficient and consisted of a reddish and velvet-like glow closely clinging to the surface of the cold cathode. Text books and investigators before that time had considered that the extremely meager amount of light given by the negative glow of a Geissler tube discharge, even on high voltage, was so small that it was entirely negligible as a possible light source.

The four following figures indicate only a few of the many varieties of this type of lamp. Figure 1 shows the original lamp with its twin wire helical electrode for A. C. current which used about one watt. Figure 2 has two plate electrodes spaced about .01 inch apart. It was, therefore, the first lamp to scientifically make use of the high resistance of the Crookes dark space. It is now widely used as a television lamp. All engineers should feel their individual responsibility towards preventing all future wars by helping the eyes of the world to catch up with its ears at the earliest possible date. It is an essential accomplishment before the world is safe for disarmament. Figure 3: this lamp has a candelabra base, a G 4½ bulb and consumes about .01 watt or .0001 ampere. Figure 4 has two parallel cylindrical electrodes in a G 10 bulb, and on 110 volts A. C. uses, normally, one milliampere.

## Positive Column Light

The basic conception in 1893 of using some superconducting gas within a small U-shaped glass tube to supplant the heated carbon filament then used in the incandescent lamp, still seemed wholly impossible even after the advent of neon. Some hope was revived by constructing a high voltage neon tube about 100 inches long and three-quarters of an inch in diameter and noting that its efficiency was even better than that of the tungsten lamp, largely because its positive column was over 100 times as long as its diameter. Even the miles of one and three-quarters inch nitrogen tubes, each about 200 feet long, in general use about twenty-five years ago, had a luminous efficiency that was high, but 20,000 volts was required. The ice on the problem of obtaining any gaseous light on low voltage was at least broken by the advent of the negative glow lamps last described, even though the efficiency of this type of Corona lamp is inherently very poor.

The high efficiency of the long positive column tube was coveted, but not its seemingly necessary accompanying high voltage, which needed to be higher the greater the ratio of the diameter to the length of the positive column. Even when this ratio was very low several thousand volts were needed to produce any positive column light. Therefore, to obtain a positive column light on 100 volts seemed hopeless. However, it was reasoned, first, that current could not flow through the gas of a positive column, like that shown in Figure 5, until it was ionized and properly supplied with electrons, and second, that the current did flow on 220 or 110 volts from one electrode to the other in Figure 4, because this low voltage was sufficient to fill the very short .007 inch gap with the necessary electrons, but of course could not produce any positive column light.

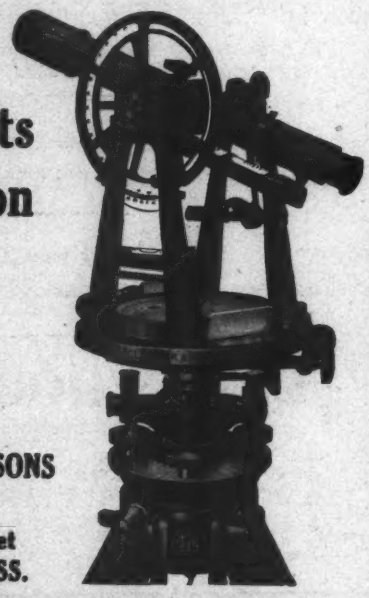
Therefore, there resulted this query, "Will a low voltage be able to sweep some of the electrons between the electrodes of Figure 4 into a positive column and therefore make it conducting, if it is afforded the opportunity?", and the lamp shown in Figure 5 was constructed about 1920. It will be noted that it simply consists of two lamps as per Figure 4 connected together with a positive column tube, and that only one of the electrodes of each of these spherical bulb lamps is connected to one of the poles of the low voltage supply circuit, and also that the remaining electrode of each lamp is directly connected to the corresponding free electrode in the other lamp.

When Switch A was closed no light whatsoever resulted, but when Switch B was closed there instantly appeared a fine positive column in C, because the 220 volts was able to bridge the two .007 inch gaps in series and the electrons thereby generated in these narrow gaps were swept by the 200 volts into the positive column tube and thereby made it conducting and the seemingly impossible problem was solved. Of course, suitable controlling resistances were added and many highly interesting modifications tried. It was the first thyratron because the amount of resistance in the B circuit controlled the current that could be much larger in the A circuit.

Figure 6 shows one of these simple low voltage positive column or gas filament lamps in bulb form. The positive column discharge of high intrinsic brilliancy or brightness passes through the small bore curved glass tubing. Difficulty at first was experienced in obtaining a life of suitable length but this was overcome by placing a vent or small hole at the center of the burner tube. Since the bulb is supplied with neon gas at about 20 millimeters this vent automatically keeps the small portion of the gas that is doing the conducting and furnishing the light, at a constant pressure notwithstanding its higher temperature. It might be termed a self-repairing gas conductor. In Figure 7 a modified form of electrode permits high current density in the positive column, yet all portions of the electrodes are far below red heat.

When only one of the terminals of Figure 7, with modifications, is used on direct current, the outer cylindrical electrode is made positive and remains

Standard Instruments of Precision



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dark, but the intense spot of light at the center of the inner electrode can easily be entirely extinguished a quarter of a million times per second, and therefore this is the Crater lamp that has received the best of television pictures. It is shown in Figure 8.

Various patents granted the author indicated that at about the beginning of the century attention was given to a number of ways of generating the necessary electrons other than the above, to lower the potential fall at the cathode. For example, another way was to use oxides of high emission when subjected to heat and there was thus made the first hot cathode low voltage lamp. One form is shown in Figure 9. The steel cathode button which operated at red heat was buried in the cylinder made of compressed lime (calcium oxide).

Instead of utilizing the natural heat of the cathode there were also constructed lamps in which the heat was obtained from a filament, either impregnated or buried in oxides, or its heat radiation was used to raise the temperature of adjacent specially prepared surfaces. Thus the necessary auxiliary circuit then first developed is now used in all X-ray tubes, rectifiers, radiotrons and thyratrons, hot cathode tube lamps, etc. Figures 10 and 11 show the original form of this electrode and its connections. Figure 12 shows a later form in which the nickel cylinder is treated to a coating of barium azide.

## The Light of the Future

Michael Faraday is generally conceded the greatest of experimental philosophers, largely because he was the first to produce electricity from magnetism. He did this in 1831 and upon this discovery rests the entire electrical industry, including "the light of the future." However, as early in his long career as 1813, he experimented with static and disruptive discharges. Geissler did not put his simple tube together until 1858, and only in recent years has its gas, its electrodes, its life, its intensity, and its necessary voltage been improved upon. Scientific men uniformly agree that all theories seem to indicate the great probability that artificial light of higher efficiency will eventually result from the still further development of gaseous conductor lamps, the inherent principles of which permit them to lend themselves to selective luminescence. The handwriting on the wall, during our time, seems to unmistakably indicate that to further increase the efficiency of light sources in general and make thereby a nearer approach to light without heat, we will need to resort to gaseous radiation, by means of which it is theoretically possible to reduce to about one-tenth the energy now required. Of course, this goal yet remains to be fully attained but a new epoch in the history of gaseous conduction light has been reached. The scientific world of today expects still further developments in electro-luminescence. Its future seems bright because its underlying theoretical principles concerning efficiency, color and intensity are all better than those possessed by the present solid conductor electric lamp. A study of the most recent and high class artificial lighting installations discloses a very marked trend towards increasing the area of the light sources. By thus decreasing to a new low level the intrinsic brightness of all light sources within the field of vision, a simulation of daylight conditions is perhaps being approached unconsciously. These effects are being obtained by using large numbers of lamp bulbs of low wattage and all provided with


# Summoning a Ghost to your bidding

The chemist Van Helmont in 1609 discovered an invisible substance, an emanation from coal, that he named "geist," meaning ghost, shortened in English to gas.

Only now do its miraculous possibilities begin to be glimpsed. Only now can modern industry, like a latter-day Aladdin rubbing his lamp to summon a vaporous genii, turn a valve and order this Ghost to any one of a hundred tasks.

From the beginning, the problem was one of piping. When Crane Co., a half century ago, set itself to develop and produce the right materials for every gas and oil purpose, it began an incalculably valuable contribution to the solution of problems that had held back the gas industry since the Chinese used hollow bamboo.

So in the development of the natural and manufactured gas industry, as in practically every other industry, the Crane line of valves, fittings, fabricated piping, and specialities have played an important part. No matter what branch of industry you enter, you will find Crane materials playing a similarly important part.

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inside frosting and these in turn are placed behind sheets of opalescent glass of unparalleled areas. Luminous tubes produce such effects naturally, and their introduction into the field of utilitarian interior illumination is likely to be rapid. They are already permanently planted over a very large area of the advertising fields, both indoor and outdoor. The based, gaseous conduction lamps are also already filling many special fields of illuminating engineering and natural evolution insures their great future.

## The Thyratron

(*Continued from page 124*)

the oxide coated cathode which may take either the form of a filament or a multicellular equi-potential cathode heated by radiation and conduction from a tungsten filament. The grid may surround the cathode or the anode depending upon the characteristics desired and is usually made of wire mesh or some perforated material. The anode in small sizes is often a small metal punching while in larger sizes is usually made of carbon. Several sizes of tube are illustrated herewith.

The rating varies by steps from a fraction of an ampere and a few hundreds of volts up to 60 amperes and 15,000 volts.

### Gases Used

The gas used is usually mercury vapor, but in some special cases argon or other inert gas has been used. The difficulty with fixed gases has been due to clean-up of gas during life but there is reason to hope that eventually this will be overcome. The operating range of pressure is roughly from 1 to 100 microns.

In making a design, consideration must be given to such factors as influence of charges on container wall and its variation during life, the possibility of electron emission from the grid, which leads to loss of control, electron emission from the anode which may cause "arc-back," the de-ionization or clean-up of residual ionization at the end of the current carrying period, and such mechanical features as are necessary for the desired service.

Experiment shows that over a wide range there is a practically linear relation between anode voltage and "critical" grid voltage at which current starts. The ratio of anode voltage and critical grid voltage may be termed the grid control ratio and is one of the constants of a given tube. By proper design it is possible to make the critical grid voltage for a given anode voltage either positive or negative.

Since the grid only exercises control before the arc has started some means of stopping the current must be provided in order to regain control. A convenient way of doing this is to use an alternating voltage on the anode. In the simple case where the load is a resistance the current automatically falls to zero at the end of a half cycle and if the grid is made negative previous to the time the anode voltage becomes positive again the grid regains control. This type of operation is useful where it is desired to have the full rectified current flow for intermittent periods.

A more useful method of control is obtained by applying an alternating voltage of the same frequency to both grid and anode, but some means of varying the phase of the grid voltage with respect to the anode voltage is also supplied. When the grid voltage lags the anode voltage by 180°, no current is rectified. As the phase of the grid voltage is advanced, current begins to flow at some point in the half cycle, fixed by the time when the grid voltage crosses the critical value, and continues to the end of the half cycle. As the grid is further advanced, current flows during a longer portion of the half cycle until when the grid and anode are in phase the full output voltage is obtained. The average rectified voltage is proportional to the portion of the cycle rectified, the current of course, depending on the load resistance. By this means there results a smooth variation of voltage from zero up to the full rectified value of the voltage used since control is exercised each half cycle.

When the external circuit contains inductance the phase angle limits of control are altered somewhat but the principle remains the same. The alterations are fairly obvious and will not be further discussed here.

In case the anode voltage is supplied from a D.C. source it is necessary to find some special means of stopping the anode voltage long enough to permit the grid to regain control. Such a means is found in a charged condenser. By closing the switch the anode is suddenly made negative and remains so during the time taken for the condenser to discharge. If during that time the ionization can be cleaned up then the grid regains control and as the anode voltage rises, current does not start to flow again.

### Applications

Among the many possible applications a few are mentioned below. They are chosen to illustrate some typical method of operation of the tube. For simplicity only single phase operation has been considered, but when desirable the thyratron can be used in polyphase circuits.

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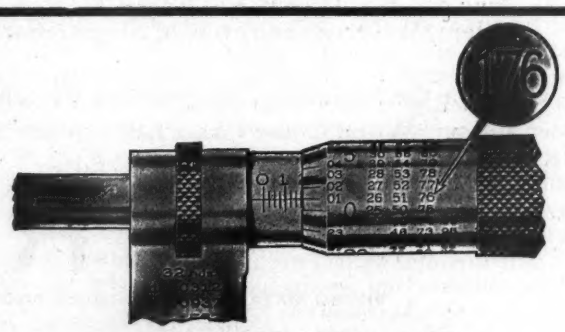

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In connection with a photo electric cell the thyratron may be used as a relay to operate a contactor or other device. The load may be the pick-up coil of a contactor or some other device which it is desired to operate by means of a light signal. It is possible to make circuits which operate either to turn on or turn off the thyratron.

In high speed line welding, where considerable trouble has been encountered with contactor maintenance, it has been possible to use the thyratron to advantage. A pair of thyratrons were connected in the secondary side of a transformer placed in series with the supply and the welding machine. When the grids were excited so as to permit the tubes to conduct, the series transformer was put under short circuit and thus practically full line voltage was impressed on the welder. During the idle time the series transformer interposed its full magnetizing reactance in the circuit and thus practically no current flowed thru the welder. Speeds of several hundred spots per minute are obtainable.

As an instance of the use of a variable voltage controlled rectifier, may be cited the lighting control for the Chicago Civic Opera. This installation has now closed a second successful season. The rectified output of a pair of thyratrons is impressed upon the D.C. coil of a saturable core reactor, which is in series with the lights. The control is by grid phase angle shift furnished by means of the output from a small induction regulator in combination with a fixed voltage. For purposes of grand master, color master, and group master control, the induction regulators are moved by means of Selsyn motors. There were 147 individual circuits and the total connected reactor capacity about 1250 kilowatts. There are 298 thyratrons in the installation. The advantage of this system is recognized when it is realized that the control board can be placed in a small space and all the controls can be reached by a single person from one position.

A somewhat similar application is found in the control for mobile color floodlighting of buildings or signs.

Finally the thyratron may be used as an "inverter." By this is meant the conversion of D.C. to A.C., that is the inverse of rectification. A simple circuit suitable for this is shown in the diagram. The direct current is fed in thru an inductance, to smooth out ripples, to the mid point of a transformer. The anodes of the tubes are connected to the terminals of the transformer and across them is placed a condenser. This is an adaptation of the circuit illustrated. Here each tube alternates in taking the place of the switch indicated in that figure. The control voltage for the grids may be supplied from a separate source or may be supplied from the output of the inverter. In the latter case, the inverter is "self-excited." This may be objectionable in some cases since the frequency tends to vary somewhat with load.

It should be pointed out that the thyratron does not supplant but rather supplements the pliotron. Each in its field is a very versatile and useful device.

For those whose interest has been stimulated for further information on the thyratron the following articles by Dr. A. W. Hull may be mentioned:

"Gas Filled Thermionic Tubes" Trans. A.I.E.E., July, 1928.

"Hot Cathode Thyratrons" G. E. Review, April, 1929; July, 1929.


BAILEY METERS

# BRAINS FOR BOILERS

A few years ago when a steam power plant underwent a heavy load demand, grimy firemen would work feverishly to keep pace with the cry for more steam. By their back breaking labor, six men could bring twelve 100 H. P. boilers from bank to full load in one hour. Coal and air were fed to the furnaces with little regard to combustion efficiency.

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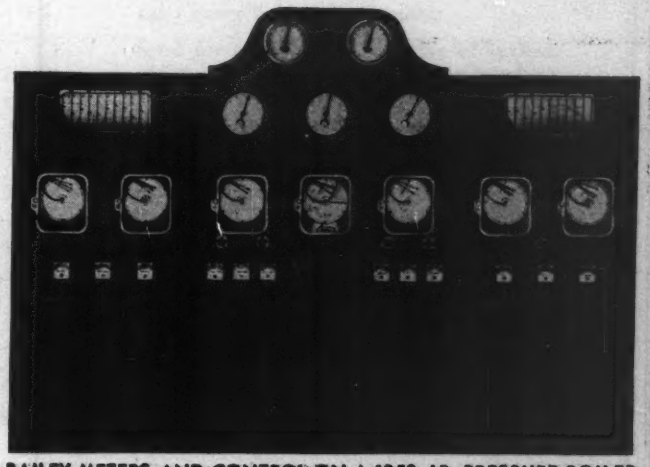

BAILEY METERS AND CONTROL ON A 1350 LB. PRESSURE BOILER

# A Million Volt Air Condenser

(*Continued from page 117*)

space is saved and the roof space used efficiently.

The condenser must withstand the full voltage of the transformer with which it is to be used. It must be free from brush discharge at the highest voltage, must be of capacity large enough to be determined with the required degree of accuracy, and must be uninfluenced by movement of overhead cranes, etc. A parallel plate type of construction has been adopted for this condenser for one million volts, each plate being twenty feet in diameter and six feet in thickness, giving therefore a radius of curvature of the surface of three feet, sufficient to suppress discharge. The plates were made of expanded metal stretched over an iron girder framework, concrete placed over the metal grid, and after careful smoothing of the surface, sprayed with zinc. Each plate weighs three tons; the high voltage plate is mounted on the transformer on a bakelite tube, the earth plate suspended by adjustable screws from the roof at a height variable between six and twelve feet above the other plate. As will be seen from the illustration, the upper plate has a guard ring placed about the central section so that only that fraction of the condenser situated within a fairly uniform field is utilized. This condenser is believed to be the largest ever constructed; its capacity is known to .2 per cent, the frequency of the supply to within .2 per cent, and the current to .1 per cent.

A few remarks may be made as to the transformer itself which is unique among the testing equipments of the world. It is the second of two 500 kv., 500 kva. transformers connected together in the well-known Dessauer circuit, and is therefore insulated against earth for 500 kv. The insulators consist of four columns of bakelite tubes supporting the weight of 55 tons ten feet from ground level. The connection to the first 500 kv. transformer is made by flexible coupling seen on the right of the photograph, the coupling passing into another laboratory where the first transformer is situated.

This fundamental method of voltage measurement affords us now an opportunity for checking the accepted curves for sphere-gaps as determined in various laboratories, and this work is in progress at the present time.

### Body Unaffected by High Voltage

An interesting though obvious verification of Faraday's ice-pail experiment is afforded by entering the lower plate of the air condenser and experiencing no trace of an electric field when the condenser is charged to one million volts. If the hand be slowly extended through an opening in the wall of the condenser streamers begin to play from the fingers accompanied by not unpleasant sensations, and streamers up to two feet in length may be taken through the body without noticeable harm.

The nature of the investigations performed with the million volt generator are in part dictated by certain pressing requirements of the industry, but for the most part are fundamental. They include a very comprehensive survey of the behavior of air, oil and solid dielectrics under power frequencies ranging from 25 to 100 cycles per second; investigations carried out at atmospheric pressures, at high pressures, and at high vacua, with oil of various grades from temperatures below zero to 110° C., and with all classes of solid insulation in sheet or tube form, or made up into assembled structures. A tank holding 20,000 gallons of oil is available for the testing of large structures under oil up to a million volts, and other containers suffice for the testing of bushings to a like voltage. The air condenser itself may be used in one arm of a Schering Bridge so that power factors on apparatus stressed to a million volts may be measured; this is the highest voltage Schering Bridge in existence. Field plotting on large structures has been performed and, as stated, the influence of various factors on sphere gaps studied.

A considerable amount of work has been done on porcelain insulators under artificial rain of various conductivities and under conditions of artificial fogging and contamination by smoke and salt deposits. These play a large part in the failure of transmission lines in industrial and coastline areas, and research on the problem has hitherto been meager. Using a specially constructed smoke chamber the various types of deposits have been studied on live insulators with most beneficial results in an extremely short space of time, and the results are now being correlated with line experience.

The problems are of great interest. Linked with all the experience and research at power frequencies is the valuable work now in progress at high frequencies and with impulsive discharges where the records of the cathode-ray oscillograph are of such vital importance. With increasing knowledge of the behavior of dielectrics the field for investigation widens rather than narrows, for we realize more and more clearly that we are still almost in complete ignorance as to the true science of dielectrics.

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*Contracting Engineers*

POWER AND LIGHTING

INSTALLATIONS

165 PEARL STREET,

BOSTON, MASS.

# Floodlighting

(*Continued from page 120*)

presents the greatest limitation but it also frequently provides the best opportunity for floodlighting. The contrast in the different building materials used often presents a wonderful opportunity for fine effects, but under all conditions the building should be studied with reference to its surroundings, and also its character before making the proposed layout.

Much better results are secured by emphasizing a characteristic part of the architecture rather than simply floodlighting the entire building with a uniform intensity of light. Present daytime building construction offers unlimited opportunities for exercising one's ingenuity in getting desirable effects. A touch of color here and there will beautify a building beyond belief, but when used, great care must be exercised. The application of color is the work of an artist rather than an engineer; rare indeed is the individual possessing these two temperaments, but to him who does, the field of color floodlighting offers unlimited opportunities to make our present-day building throb with beauty and appeal.

No building is too dignified to be floodlighted. Take as an example the National Capitol at Washington. The dome of this building is floodlighted from four main banks of projectors located on the Senate and House wings. The modeling is then secured by placing searchlights at various locations on the roof as well as on the fence located on the opposite side of the street. The dome is plain white, and is accredited with being one of the most beautiful domes in the world; lighted, therefore, it is more specifically called to the attention of the millions of people who throng the Capitol on gala occasions.

In lighting a dome of this character, it is necessary to study carefully the placement of the projectors so as not to cause distorting shadows, at the same time providing sufficient light and shade to give a proper relief which would not result from plain flat lighting. The Capitol was lighted in 1917 and has received universal commendation from both the lay and technical press. It has been an incentive to many states to light their state capitol buildings. This should be conclusive evidence that the most dignified buildings lend themselves to floodlighting.

On the other extreme, there is no building too lowly to be floodlighted. Numerous are the subjects that present themselves for floodlighting treatment and to the specialist is offered unlimited opportunities to exercise his ingenuity in painting beautiful pictures on the skyline.

The color of the building is one of the governing factors in determining how economically it may be lighted. It is obvious that a light-colored building in dark surroundings can be lighted more economically than a very dark building in bright surroundings. We see by contrast and the less the contrast the greater the intensity necessary to provide good visibility. We normally say that a dark colored or a dirty red brick building cannot be economically floodlighted, yet frequently where there is white terra cotta trim, under favorable surroundings, a very attractive installation may result; that is, if the projectors are properly placed so as to emphasize the contrast.

As an extreme case of floodlighting a dark-colored building, we might cite the American Radiator Building in New York City. This is built of black brick, the top being decorated in gold, and by a skillful plac-

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ing of the projectors to get the specular reflection of the uneven gold surfaces, a most attractive installation has resulted.

Conversely, we have the white marble Dade County Court House at Miami, Florida, which has the entire building lighted to a high intensity by means of 164 500- and 1000-watt floodlighting projectors with a total of 100 K.W.

### Color Combinations

The combination of a small amount of color to emphasize the building is illustrated in the Fisher Building in Detroit. This stands at the head of Second Boulevard and is visible for many miles. Here the niches above the balconies, which are normally in shadow, are brought out in deep red, securing a most beautiful effect.

The Terminal Tower in Cleveland, Ohio, is an interesting installation, and clearly points out how floodlighting may be used to emphasize architectural detail. The tower, spiraling toward the heavens, is in the form of a square as far up as the 34th floor. Below this floor is an alcove behind a peristyle, which is lighted to a rather high intensity, by means of trough reflectors behind the columns; leaving the columns completely in silhouette. Above the 34th floor are various setbacks and columns which are brought out in detail. The columns of the upper floors are lighted from in front to a low intensity, and behind the columns is used a much higher intensity which is secured by placing projectors between the columns and directing the light back. This provides a slight relief to the columns but leaves them still visible.

Mobile color is becoming more and more popular. Different colors are alternately thrown on a building, one color fading into another and finally a clear light is brought up which washes out all the color and for a short space of time brilliant white lighting is produced. A recent outstanding installation of this type is the Staley Building in Decatur, Illinois. On this building the color is controlled by means of thyratron tubes. This is the first outdoor floodlighting installation having this type of control. It provides a very smooth variation from one color to the next and offers unlimited opportunity for change in the control. A total of 195 projectors is used; 156 of the total have blue, red, or amber colored lenses.

Another installation of a somewhat similar character is the Philadelphia Electric Building in Philadelphia, Pa. Mobile color is used here in the same general manner, except it is controlled by mechanical means through motor driven resistances. Resistances are alternately cut in or out of the various banks of projectors, bringing up the various colors and blending one into the other with the color finally all diluted with clear light. The cycle is then repeated. Any number of combinations may be secured by simply changing the gear ratios of the driving mechanism. When all the light is on the building the power expended amounts to about nine watts per square foot of area.

Architects are becoming more and more interested in the design of buildings which lend themselves to floodlighting. They are providing locations where it is possible to place projectors, and are using materials of such texture that satisfactory results will obtain. Our city streets of the future, will be lined with buildings, beautiful by night as well as by day—silent tributes to architectural progress and engineering ingenuity.

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AND

CONSTRUCTION

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BOSTON, MASS.

## Application of Electricity

(*Continued from page 119*)

cathode a subchloride is formed in place of the metal, and this subchloride does not conduct well, so here the process stops. A lead-barium alloy, however, can be made in the same way as the calcium-lead alloy.

Beryllium is made in Germany on a small scale, by fused salt electrolysis. In 1929, 1000 kilograms were produced, valued at about $110. a pound. Beryllium makes valuable alloys with copper, nickel, cobalt, iron, and aluminum. It is 17 times as transparent to X-rays as aluminum.

A number of important products are made in electric furnaces by means of the temperature alone. The most important technically are the carbides of calcium and silicon. Nearly all metals make carbides, but their properties are quite variable. Silicon carbide is a crystalline substance nearly as hard as diamond, while calcium carbide has no value as an abrasive and reacts with water to produce acetylene. Another important property of calcium carbide is its ability to react with nitrogen to form calcium cyanamide, and this reaction is carried out on a large scale. Other products of electric furnaces are graphite, carbon bisulfide, phosphorus, fused quartz, fused alumina, fused magnesia, and silicon. Silicon is produced by the reduction of quartz by carbon in the electric arc furnace. It is used for deoxidizing steel, for light alloys, for making acid resisting iron alloys, and for other purposes. By adding steel turnings to quartz and carbon, ferrosilicon is made. Many other ferro-alloys are similarly made.

Ozone is made by the passage of the brush discharge through air or oxygen. It is present in the atmosphere, especially after thunder-storms. It is a power-

ful oxidizing agent and disinfectant, so is used to purify water supplies and cold storage warehouses.

The oxidation of nitrogen takes place in a different kind of electric discharge called the high tension arc, which may operate at 20,000 volts. The arcs are several meters long; they are formed in a narrow chamber through which air is passed. The air coming from the furnace has about 1.5 per cent of nitric oxide, which is cooled and then absorbed in water with the production of nitric acid.

Statistics as to the total amount of power used in electrochemical industries are not available. However, 200,000 kilowatts capacity in direct current machinery is purchased yearly by growing electrolytic industries throughout the world, and this does not include that used for carbides, ferro-alloys, steel refining, and so forth.

## Electrical Engineering

(*Continued from page 116*)

of these men that the use of electricity has permeated so thoroughly our domestic and industrial life. The scientific discoveries of the early part of the century, and the marvellous inventions of the latter part but gave these men the necessary foundation upon which to build. Without their economic foresight and genius for organizing, the results of scientific discovery and invention would have probably been most meager.

### Incandescent Light in 1879

In 1879 Mr. Edison was successful in his search for a material which would have the necessary properties to serve as a filament for his incandescent lamp. On September 4th, 1882, he put in operation at 257 Pearl Street, New York City, his central electric power plant. This was the first commercial central power plant in the world, although it is true that eight months earlier an electric power plant for demonstration purposes had been put in operation in London, only to be abandoned two years later. Mr. Edison's station opened with one engine and generator which could supply four hundred of his incandescent lamps, each taking about seventy-five watts. By the end of September three more engines were put in use, bringing the total capacity up to twelve hundred and eighty lamps, and supplying fifty-nine customers.

This first month's growth was prophetic of the history of the central power plant industry. Last year in the United States alone the capacity of the central power plants was 31,836,000 kilowatts supplying 24,700,000 customers. This represents an investment of close to twelve billion dollars. At present it is estimated that 86,000,000, or over 70 per cent of the inhabitants of the United States, live in electrically-lighted houses. Such is the story of the central power plant, an industry less than fifty years old.

The electric railway started with a little line, one and one-half miles long at Lichterfelde, near Berlin, Germany, which was opened for traffic in May, 1881. The first successful commercial line in the United States was devised by Frank Sprague and put in operation in Richmond, Va., in 1887. Each car was equipped with two motors developing seven and one-half horsepower each and capable of driving the cars at a speed of ten miles an hour. Last year in the United States alone there were upwards of 37,500 miles of city and interurban electric railways carrying daily more than 40,000,000 persons and the cars on many interurban lines attain a speed of over sixty miles an hour.

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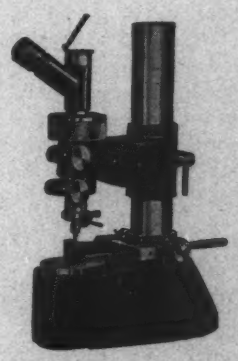

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OPTICAL COMPANY
ROCHESTER NEW YORK

While the automobile and motor bus during the past decade have somewhat impeded the growth of the city and interurban electric railways, the electrification of existing steam railways has shown steady progress, so that now in the United States there are twenty-one steam railroads having electrified portions of their system totalling over 4400 miles. The indications are that within the next few years the electrification of existing trunk lines of steam railroads will be among the most active electrical engineering projects.

The story of electric communication in this country begins with the establishment by Samuel Morse in 1844 of his first telegraph line between Washington and Baltimore. The invention of the telegraph was immediately made use of by the steam railroads to direct the operation of the trains, and it is hard to overestimate the value which this means of communication has been to the problem of transportation. The two great industries, communication and transportation, have grown up side by side.

### First Submarine Cable

In 1866 Cyrus Field succeeded in laying a successful submarine cable joining the United States and England. At the present time all the world is linked together by submarine telegraph cables. In America the prestige of the telegraph has been overshadowed by the telephone and it is hard for us to appreciate the greatness of the telegraph industry and its effect upon the commercial and political life of the world.

In 1876 Alexander Graham Bell, in a warehouse on Court Street in Boston, developed the first practical telephone. Today there are in use in this country 20,250,000 telephones with a daily average of 82,900,000 telephone conversations. This system is being added to at such a rate that the yearly cost for replacement and new equipment is about double the total cost of building the Panama Canal.

The story of radio starts with the theory advanced by Clerk Maxwell in 1865 that electro-magnetic waves exist which have the same characteristics as light waves. Twenty-three years later Hertz produced and measured these waves. Then Senatore Marconi, a wealthy young man just out of college looking for something in which to interest himself, and becoming acquainted with the researches of Sir Oliver Lodge in England and Professor Dolbear in the United States, took up the problem of developing the use of these so-called Hertzian waves into a system of communication by wireless telegraphy. In 1896 he applied for a patent and the following year erected on the Isle of Wight the first Marconi station with a communication radius of fourteen and one-half miles. Fessenden conceived the idea of using a continuous stream of electro-magnetic waves for a wireless system of telegraphy by heterodyning the stream at the receiving end. Fleming's valve and DeForest's audion based on the researches of Richardson and J. J. Thompson, provided apparatus for the rectification and detection of modulated waves and opened up the modern field of wireless telephony and broadcasting. With the advent of the radio have come almost numberless forms of electronic apparatus. The vacuum tube bids fair to make such changes in the use of electricity within the next few decades that this age will be known not as the "age of electricity" but rather "the electronic age."

The photo-electric cell, that "electric eye", is so sensitive to light that it is becoming one of our most effective relays. Already it is reported that one of the large steel companies is using this means to control the covers of their soaking-pit furnaces. When a travelling-crane operator desires to open one of the furnaces he simply projects a beam of light on the corresponding photo-electric cell and the pit opens. By this means, complicated control and wire connections to the travelling crane are eliminated.

Electronic devices in the form of tubes filled with neon and argon have already largely taken the place of filament lamps for display lighting. Huge mercury arc rectifiers of thousands of kilowatts capacity are rapidly displacing rotating machinery where large quantities of alternating-current power must be converted to direct-current.

The thyratron, another piece of electronic apparatus, has come into prominence as a means of converting direct current into alternating current and may effect radical changes in the present system of transmission of electrical energy.

Television is already here on an experimental basis and it may be but a short time until it will become a commercial reality.

In order to supply the equipment for these numerous electrical industries which have already acquired such colossal proportions and are growing at such an almost unbelievable rate, it is necessary to have equally large research, design and manufacturing organizations. It is estimated that the value of the products turned out by electrical manufacturers in 1930 was nearly two billion dollars. Some idea of the growth of this part of the electrical industry may be obtained from the fact that twenty years ago the value of this same class of manufactured output was only about one-seventh as much. It is significant to note that the value of vacuum tubes and radio apparatus manufactured in 1930 was greater than that of any other electrical apparatus. In 1910 the value of such apparatus was almost negligible. So rapid has been the growth of electrical manufacturing industries, and so changing in the character of its output that the president of one of the greatest electrical manufacturing companies is reported to have stated recently that last year thirty per cent of the income of his company was derived from the manufacture of apparatus which was practically unknown ten years ago.

It is fortunate that this article is confined to history. A prophecy of even the next ten years would tax the powers of a Jules Verne.

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# Michael Faraday

(*Continued from page 113*)

the Royal Institution to succeed Sir Humphrey Davy in 1825; and, it is the subsequent period of his activities which resulted in those great investigations in electro-magnetism which have made his name famous for all time.

I suppose it is characteristic of the purpose of the applied mathematician that he shall lay hold of the cornerstones, or hypotheses, which control the course of events in the field he is studying, and shall then seek the full consequences of these hypotheses in their richest and most elegant forms. Although Faraday was not a professionally trained mathematician, he possessed, in an exceptional degree, the faculty of ferretting out, in a form which was exact, the essential elements which entered into the subject. It is one of the characteristics of his way of thinking that he could lay hold of the essential elements, in a qualitative way, long before he was able to place that exact significance to them which is associated with quantitative relationships. This faculty is exemplified particularly in his attitude towards what he calls the electro-tonic state of a circuit. He had arrived at the conclusion that the induction in circuits occurred only during the intervals when the inducing current was changing or when the circuit carrying it was in motion. And the characteristics associated with the various phenomena in this field called in his mind for the existence of a certain quantity associated with each circuit, a quantity in terms of whose changes the phenomena of the induced current could be discussed. In his pictorial way, he regarded this state as a certain state of the matter of which the circuits were composed.

At a later time when he had visualized his thoughts in terms of tubes of magnetic induction, the quantity associated with this state took the form of a quantity proportional to the current in the circuit multiplied by the flux of induction through the circuit. In the hands of Maxwell, this quantity assumed the aspect of an electro-kinetic momentum of the circuit. There is, I think, a danger in relegating to too small a realm of triviality this great concept of Faraday. If one thinks of an electro-tonic state as something with no more richness of content than that of a mere symbol of something whose changes produce the induced currents, it is possible that the charge of triviality might be invoked. It is probable, however, that in the mind of Faraday, his concept of the electro-tonic state and of the quantity whose magnitude was associated with it, was adorned with many pictures as to its nature and significance, pictures which aided him to spell out in detail qualitatively at any rate, the main facts of the electro-magnetic field, and to arrive in substance at the same conclusions as those reached later in such elegant form by the mathematical treatment of Maxwell. It was Maxwell himself who realized at the time, possibly more forcibly than any other of his contemporaries, the profound significance attached to Faraday's concept of an electro-tonic state, even though that concept may appear naïve in its expression in the light of the later, more mathematical form, in which the story was told.

### Visualized Phenomena Studied

Although Faraday used his imagination to the utmost for the purpose of visualizing the phenomena which he was studying, he always made models his servants rather than his masters. This characteristic is well exemplified in his treatment of the so-called

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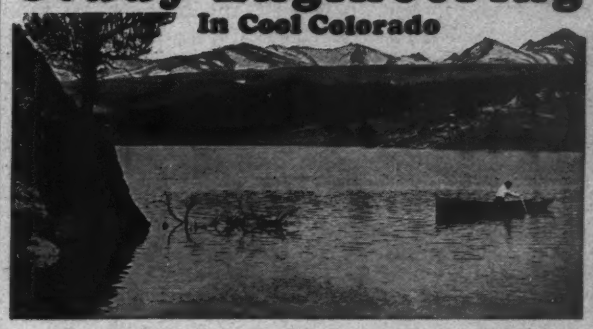

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problem of unipolar induction, a problem which presents even at the present time, considerable difficulty to many who do not possess the mathematical training in which to discuss the question from the point of view of Maxwell's equations, but nevertheless have found the concept of tubes of induction a powerful one to serve most of their ends in engineering practice. To one who adopts the concepts of tubes of magnetic induction as attached to a magnet, and moving with it, there must be considerable difficulty in attaining logical consistency in thought when he is asked to adjust his thought to a concept which involves the idea of the steel of the magnet as revolving while its tubes of induction remain stationary. He is apt to wonder what it was that he believed when he spoke of the magnet as moving with its tubes of force.

However, if one reads Faraday, one finds that these matters present no difficulty whatever to his mode of thinking. Although on one occasion he may have pictured the tubes of induction as bound to the magnet like wires soldered to it, he is readily able to modify his picture of the relation of the tube to the magnet so as to permit the rotation of the latter without participation of the former. He possesses the capacity of using the thunder of the most materialistic of thinkers, then of rushing off to realms of thought which might be expected only from the most sophisticated mathematicians, and yet of welding everything into a new materialism of his own, a materialism molded to be consistent with the facts rather than with vague preconceived notions of what it ought to be, founded upon nothing in particular.

At the present time, when our views as to the significance of an electric current have become so complete, it is well to remind ourselves that in the early stages of the science, it was by no means obvious that those things which we now call electric currents were of the same character, regardless of their mode of production. The realization of a current of electricity from electrostatic charges, from a voltaic cell, and from electro-magnetic induction, involved such a diversity of methods in the production of the phenomena, that, in the early history of the subject, the question of the identity of electric current produced by different means was one whose solution was by no means obvious. The problem was one which interested Faraday profoundly; and, he was not satisfied until he had convinced himself by an exhaustive series of experiments as to the identity of the currents of electricity from different sources. In the course of these investigations, he laid the foundation of our present views on electrolysis, and formulated the two important laws which go by his name.

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## Researches Fall into Two Groups

Faraday's experimental researches in electricity fall into two main groups, those pertaining to the ten years from 1831 to 1841, and those concerned with the later period of his life. The former group contains the most important representatives of his genius, including as it does the discovery of electro-magnetic induction, and his investigations in electrolysis. In 1841, Faraday suffered a serious breakdown in health which necessitated a year's trip abroad. He returned much refreshed, and improved in health, but it is doubtful whether he ever regained his full vigor of earlier years. His first investigations after his illness have to do with the rotation of the plane of polarization of light, a series of researches to which he was led as a result of a profound conviction, which he held, as to the unity of the forces of nature, a conviction which urged him to try and find some relation between light and electro-magnetism. Later we find him seeking a corresponding connection between electro-magnetism and gravitation, but without success.

To this period of Faraday's activities belong his discovery of the magnetic characteristics of materials and his exhaustive examinations of these phenomena in numerous substances, including gases. He becomes particularly interested in the magnetic characteristics of oxygen, and thinks that he sees in it, when combined with the temperature variation of the earth's atmosphere, a potent influence in relation to the variations of terrestrial magnetism. To the later period of his activities belong those speculations upon the nature of light, in which he tried to visualize waves of light as undulation of his lines of thought, speculations which contain the fundamental germs of truth as later exemplified in the mathematical developments of the electro-magnetic theory.

As age crept on his health gave him more and more trouble, particularly in the form of forgetfulness. As he felt his powers weaken, he laid aside his duties one by one. His last lecture was delivered in 1862 and the same year saw his last experiment. He was invited to assume the presidency of the Royal Society but declined. It was inevitable that the managers of the Royal Institution should deem it fitting that as his career drew to a close he should be asked to be president of the Institution to which he had brought such lasting fame; but, he felt that the duties of this position, if conscientiously performed, would be beyond his powers at this time, and he was not one to take the task and in carrying it through fall below the standard set by his very high ideals. The closing years of his life were spent near Hampton Court in a house placed at his disposal by the Queen in 1858; and it is a happy thought that in spite of the weakening of his powers, time treated him kindly as regards his general health. He suffered no disease and his end came without pain on the 25th of August, 1862 while seated in a chair at his desk.

Faraday's powers of reasoning stand as a typical example of the power of intuition in physics, when used in the right way, an intuition ready to utilize the most materialistic pictures of the phenomena as an aid to thinking, but one controlled always by the discipline

of the facts—an intuition which enabled him to strike, sometimes by devious routes, but always surely and with certainty, to the goal. This characteristic was well summed up by one, who, in speaking of Faraday's uncanny power of hitting upon the essential of the phenomena remarked, "He smells the truth."

# Arc Welding

(*Continued from page 115*)

given off. The carbon monoxide being one of the greatest deoxidizers known, combines with the oxygen of the atmosphere surrounding the arc, thus leaving no oxygen or nitrogen to combine with the molten weld metal in the process of deposition.

This shielding of the arc in electric welding produces welds with exceptional physical and chemical qualities. These welds have a tensile strength of ten to twenty thousand pounds per square inch greater than mild rolled steel. This is possible because the oxidation in the weld metal, which tends to weaken and embrittle it, is actually less than in the parent metal. The extreme ductility and high resistance to corrosion of shielded arc welds are due to the efficiency of this shield.

## Test Results

The effects of corrosion are illustrated by a sample made with two different welds. This sample was immersed in a 10 per cent solution of sulphuric acid for 72 hours. One weld was made with an uncoated electrode. Inspection revealed that this bead was badly pitted in the corrosion test. The other weld was made by the shielded arc. The difference in the effects of corrosion on these two beads was marked.

Another test bar was formed by butt welding two pieces of steel plate by this new method. The surplus weld metal was machined off so that the weld was only as thick as the original plate. Two holes were then drilled through the weld and the sample pulled. When the break occurred in the plate, the pull on the sample was 54,000 pounds per square inch. The stress on the weld metal was 60,900 pounds. The higher stress on the weld metal was due to the fact that the cross sectional area of the weld was reduced by the two holes drilled through it. Before testing, the round drill holes were 0.182 inch in diameter. After the sample was pulled this dimension was increased to 17/64 inch, or an elongation of from 40 to 45 per cent.

A test bar composed entirely of shielded arc weld metal was made. The weld metal was machined into a rectangular bar and then pulled. The test showed that the weld metal had an ultimate strength of 62,500 pounds per square inch and that the yield point was 24,500 pounds per square inch. The elongation in two inches was 30 per cent.

Wherever electric arc welding is being used it is proving its worth when compared with other fabricating processes and other methods of construction. The many advantages of this modern process, combined with those which may be obtained for a certain product or industry by the adoption of arc welding, make it a most desirable process in metal working industries.


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TABLE OF CONTENTS


| | PAGE |
|---|---|
| Taking Stock in 1931. By Dr. Karl T. Compton | 153 |
| The Chemical Identification of Solids by Crystallography. By Dr. M. J. Buerger | 154 |
| The Hudson River Bridge. By Donald G. Fink | 156 |
| Glass Bottle Manufacture. By Charles T. Stewart | 158 |
| The Engineer's Place in Public Utilities. By Thomas E. Penard | 159 |
| Turbine Electric Ship Propulsion. By Frank V. Smith | 161 |
| Editorials | 162 |
| Engineering Notes | 164 |
| Recent Books | 166 and 177 |
| Faculty Sketch. Professor George L. Hosmer | 168 |



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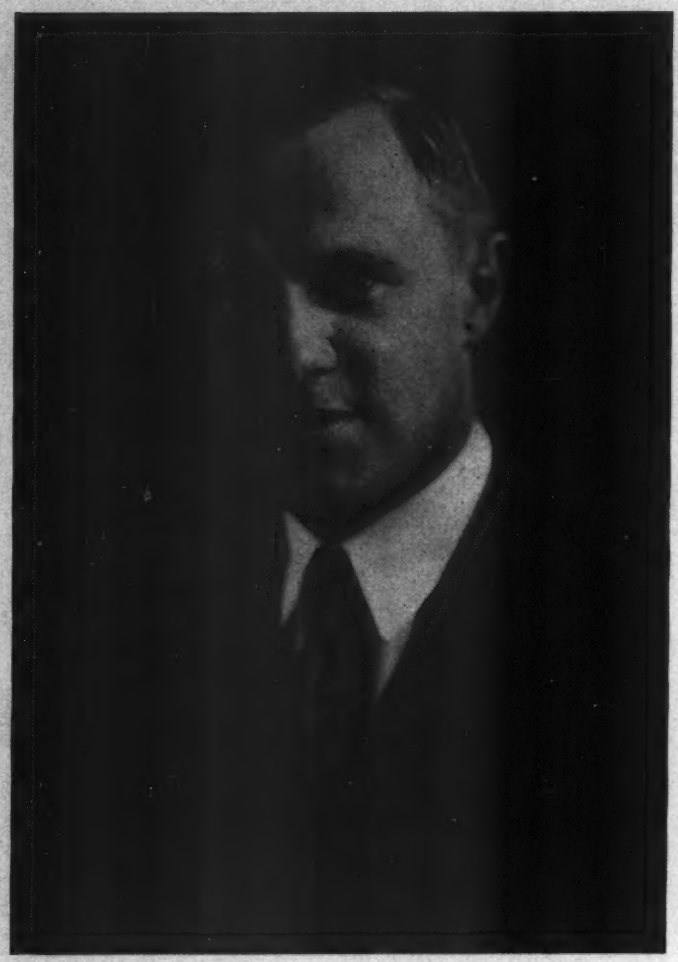

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## DR. KARL TAYLOR COMPTON

**President**

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FROM a rich and varied background, Dr. Compton draws the material for his discussion, "Taking Stock in 1931." He was born at Wooster, Ohio, the son of a clergyman, was educated at Wooster College and Princeton University, was instructor in chemistry and physics, Professor of Physics and Chairman of the Department of Physics at Princeton and is now President of Technology. He holds honorary degrees from the country's leading universities and scientific institutions, is a member of many scientific societies in many of which he holds high positions, is Consulting Physicist for various organizations, and has written approximately 100 publications dealing with physical subjects. Last spring he was awarded the Rumford Medal, one of the highest of scientific distinctions, for his work in spectroscopy and thermionics.